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A BRIEF HISTORICAL SKETCH OF OCCUPATIONAL MEDICINE

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THIS brief historical sketch is being presented primarily for those readers who may not be familiar with the events which have led to present concepts in occupational medicine. The individual papers in the symposium deal with specific topics; this sketch may help to give a picture of the entire field as it exists today.

EARLY HISTORY

In preparing an historical sketch, there is always difficulty in knowing just where to begin. Some historians trace the origins of occupational medicine back to the Paleolithic Age.[1] The ancient Egyptian papyri, particularly those of Edwin Smith and Selier,[2] contain descriptions of occupational injuries and occupational hazards.

The writings of Hippocrates contain numerous allusions to relationships between occupation and disease and the same holds true for Galen. In later periods the names of such famous personages as Agricola, Paracelsus, Fallopius, and Bartholin are associated with occupational medicine.[3]

The year 1700 may be considered as marking the opening of the modern era in occupational medicine. This was the year of publication of the great work *De morbis artificum diatriba* by Bernardino Ramazzini, an opus which earned for its author the epithet "Father of Industrial Medicine."

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For more than 100 years following the publication of Ramazzini's book, very little of significance was added to the occupational health literature. During this period, however, the industrial revolution began, bringing with it the development of factories and a new set of occupational health problems. Much of the nineteenth century literature deals with deficiencies in the general hygienic conditions in factories, but articles and books on specific hazards also began to appear.

THE TWENTIETH CENTURY

Recent developments in occupational medicine in the United States have been characterized by several fairly distinct trends. Starting in about 1910, there was a period of about 20 years in which major attention was directed to the prevention of industrial accidents and injuries. The development of programs of accident prevention were stimulated by the enactment of workmen's compensation laws and the emphasis on traumatic injuries led to an orientation that was primarily surgical.

During the 1930's the emphasis in occupational medicine began to shift from trauma to toxicology, in other words, from surgery to medicine. A number of state health departments established divisions of industrial hygiene shortly after federal funds were made available for this purpose under the Social Security Act of 1935 and the U. S. Public Health Service intensified its activities in the occupational health field. Among the significant advances in this period was the development of methods for measuring atmospheric contaminants in work places and for the control of potentially harmful occupational exposures. A new profession, that of the industrial hygienist, came into being, embracing technical skills of the analytical chemist and the ventilation engineer. Important progress in preventive medicine was made through industrial hygiene, that is, assessing the working environment and instituting corrective measures before poisoning occurred. The role of the physician in industrial hygiene was to check the validity of hygienic standards and the efficacy of control procedures by studying the health status of workers who are exposed to potentially harmful environments.

During the intensive industrial effort connected with World War II, the application of principles of industrial hygiene resulted in an incredibly fine record of occupational health. An outstanding example of this was seen in the production of TNT. At the time of World War I there had been dozens if not hundreds of casualties due to poisoning in the manufacture of explosives. During World War II, with TNT production many times greater than in 1917 and 1918, cases of serious poisoning were practically unknown.

The manpower shortage which was present in the United States during World War II led to an important new development in occupational medicine. Employers, competing for a limited supply of workers, were forbidden by the "wage-freeze" laws to offer higher pay to attract employees. This led to the creation of so-called fringe benefits, including employer payments for various types of health insurance. With the war's end the employer no longer found it necessary to offer these fringe benefits, but the labor unions insisted that they

VOL. 9 195

be continued. The resulting dispute ultimately reached the Supreme Court of the United States which ruled that health and welfare provisions were proper matters (along with wages, hours, and conditions of work) for inclusion in collective bargaining agreements. The result has been large scale participation of employers in the purchase of medical care and hospitalization insurance, either directly or through union welfare funds. It is this movement which led to the phenomenal growth of voluntary health insurance during the past 20 years.

EXTENSIONS OF OCCUPATIONAL MEDICINE AND INDUSTRIAL HYGIENE

The recent upsurge of interest in atmospheric pollution found the country almost totally lacking in persons qualified to deal with the problem. It was soon recognized, however, that many of the principles and techniques which had been developed by the industrial hygienist could be applied to the study and control of air pollution. Thus the industrial hygienist moved his sampling and analytical procedures from the air inside the factory to the air outside. Today's experts in air pollution control were yesterday's industrial hygienists.

Occupational health hazards in the use of x-rays and radium have been known for more than 50 years. With the advent of nuclear fission the magnitude of the potential hazard reached new and staggering proportions. Protection against harmful effects of occupational exposure to ionizing radiation depends upon the application of the principles of industrial hygiene. The subspecialty of "health physics" has recently been created to deal with the occupational health problems of ionizing radiation. The health physicist is, in effect, an industrial hygienist who has learned to use a Geiger counter.

In our present economy the existence of toxic materials is no longer confined to the industrial environment. Every housewife is potentially exposed to an array of detergents, spot removers, and other chemicals, many of which are distinctly dangerous. The food industries—production, processing, packaging, and preservation—involve the use of an array of toxic compounds. The industrial toxicologist is now being called upon to deal with some of the problems arising out of the increased use of so-called economic poisons.

Just as the atomic age brought with it increased hazards from radiation, so the "jet" age presents new hazards due to noise. It is true, of course, that the existence of harmful intensities of sound antedated the jet aircraft but the latter has stimulated interest in and attention to the damaging effects of noise. Occupational hearing loss has recently become a major problem in industrial medicine and it offers a new field for the application of the preventive principles which are known to be effective in controlling other environmental hazards. The sound level meter and octave band analyzer have become a part of the armamentarium of the industrial hygienist and the audiometer has found its way into the examining room of the industrial physician.

Modern occupational medicine embraces many other interests in addition to those just mentioned: problems of chronic illness and the aging work force, vocational rehabilitation, mental health, and human relations, to mention but a few. To meet the challenges of this broadening specialty, research and training

programs have been established in a number of leading universities. The American Academy of Occupational Medicine was organized in 1946 and it has played an important role in raising professional standards. A specialty board in occupational medicine, under the American Board of Preventive Medicine was formally recognized in 1956 with certification requirements as rigid as those of the other Boards. The symposium which makes up this issue of the JOURNAL OF CHRONIC DISEASES has been designed to illustrate some of the current interests in this fascinating field.

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VOL
9
195

THE CHRONICALLY ILL ARE EMPLOYABLE

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VOL.
9
959

THERE has been a great deal of discussion concerning the abilities of the variously handicapped to perform useful work in industry. In agreement with current popular thinking, we consider the broad use of the term "handicapped" to include all people who have a serious medical, emotional, or purely physical problem that in some way places definite limitations on their availability for gainful employment. These people are rightly considered the chronically ill. This is in no way meant to detract from the ability of these people to perform their particular job assignment in excellent fashion. Medical literature in recent years ably demonstrates the feasibility of considering for employment the chronically ill.[1-3] When the socioeconomic factors are considered in their true perspective, the conscience of industry needs very little prodding to assume the responsibility of considering the chronically ill for employment.

This problem leads us to one of the major functions of an industrial medical department. Rarely does a company establish a definite policy on the employment of the handicapped. Those farseeing companies that do have a policy will universally state their willingness to accept for employment any chronically ill candidate who can compete in the open market for a job. That is all the handicapped person asks from industry. Due to this general lack of a formalized program, the medical department of a company can assume the responsibility for seeing that prospective employees (as well as those already employed) are properly evaluated for job assignment. Taking this positive viewpoint we can place and keep employed the majority of the chronically ill that come to us for evaluation. This is a service to the individual and a credit to the industrial community. Such possible misgivings as (a) increased compensation costs, (b) greater absenteeism, (c) heavy burden on company-sponsored insurance plans, (d) work inefficiency, and (e) increased labor disputes have all been allayed by the factual report recently published by the Human Resources Corporation.[4]

JOB PLACEMENT

A vital stage in the evaluation of any chronically ill employee or prospective employee is the job placement examination. The manpower coordinator or employment director must work in close harmony with the medical department

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in seeing that every handicapped person is placed in the occupation best suited to his existing capacity and therefore least likely to provoke future problems.

In evaluating an individual for job assignment, most medical departments utilize a system of numerical classification for communicating with the personnel department. Employees or potential employees are classified numerically from I to IV, based upon a total physical or psychologic impression gained by the examining physician.

Class I.—Candidates or employees who have no significant physical or emotional conflicts toward employment and in whom a normal response may be anticipated in their future employment are classified as Class I. As time passes, the original classification may be changed as disability evolves and job potential decreases. Meanwhile an employee is considered by medical standards to be fully capable of performing all his duties.

Class II.—This category signifies a minor physical condition which does not restrict the complete performance of a job assignment in any way.

Class III.—These employees have a significant medical disability but are capable of performing adequately their assigned job classification. As possible future job changes are considered they must first be discussed and cleared by the medical department before reclassification. To further avoid misunderstanding, the term "MED" is added to the Class III designation. Thus, an employee classified as "III MED" will have this restriction clearly and prominently displayed on his application, personnel record, kardex, and master file for future reference. Organized labor has cooperated wholeheartedly in our efforts to employ and retain the chronically ill, giving us complete freedom in the disposition of cases that evolve from added disability. Every effort is made to place new "III MED" employees in occupations that will not add to their existing disability nor limit their full performance of their duties. Older employees may require limited duty status, a possibility in many occupations.

Class IV.—This category means that the existing physical handicap demands rejection for the job assignment under consideration but not necessarily for another possible assignment in keeping with other skills which the individual may possess.

Reclassification.—The classification placed on the various personnel records follows a worker throughout his employment, but the medical conclusions relative to an individual do not remain static. It becomes necessary to maintain an adequate follow-up program. Periodic medical examinations are performed for as many employees as possible. Complete annual physical examinations are given to the supervisory and executive force. Large segments of the plant population are examined because of a hazardous or potentially toxic exposure. Mass screening is often performed, as in chest surveys and diabetic or immunization programs. These help to bring added information to our attention.

By far the major source of additional medical information comes from the practice of careful scrutiny of employees who have been disabled from work for 5 days or more. This procedure is not intended to be used as a control of sickness absenteeism. The problem of lost time for whatever cause is not the responsibility of the medical department. The alert plant nurse or industrial phy-

sician must use this contact to uncover potentially dangerous medical situations. Employees who have had an extended medical leave of absence (one month or more) should be examined by a physician. Most chronically ill cases within our organization are discovered at this time rather than at a time of employment. Even when the classification "III MED" is applied at a date later than the time of employment, it has the same legal significance for use by the Special Fund of the Workmen's Compensation Department in states that have a Second Injury Law.

The medical department has a grave responsibility in the case of many job changes. Some requests may be initiated by the medical department when a serious disability is discovered prior to returning an employee from a medical leave of absence. Others originate from the employee, his personal physician, or his supervisor. Others arise from management, as in cases of geographic transfers, overseas duty, prepromotional examinations, etc.

When, because of new or added disabilities, an employee can no longer perform his assigned duties he is referred to the Personnel Department for reclassification. Here his skills are evaluated, available jobs are analyzed in relation to physical capacity, and job placement usually results even though it may require concessions according to strict adherence to the labor contract.

If, however, in view of the severity of the medical disability, the employee cannot be placed in the company, he is given a medical leave of absence until the expiration of his disability insurance coverage. At the end of this time (approximately 6 months to one year) he is re-evaluated and prepared for early medical disability retirement.

CLASSIFICATION OF DISABILITIES

In our company we have approximately 1,200 employees (or 7.8 per cent) who have medical disabilities that require a "III MED" classification. These embrace a wide variety of chronic illnesses or physical impairments. Table I shows the general distribution of these disabilities.

Approximately 10 per cent of these employees have more than one illness which is significant enough to be classified as "III MED" alone.

As seen in Table I, cardiovascular disorders make up 36.2 per cent of our handicapped population. An analysis of this component shows that corcnary artery disease (including angina pectoris), coronary insufficiency, and coronary thrombosis with myocardial infarction consititute the largest segment. Rheumatic heart disease and arteriosclerotic heart disease (exclusive of the first group) follow in frequency. Table II shows the breakdown of heart disorders.

In general, an employee with cardiovascular disease can maintain his usual occupation although sedentary work in keeping with diminished cardiac reserve may be preferred. Limitations on weight lifting, climbing, overtime work, driving, etc. may be enforced. Recent attention to the effects of physical exertion on serious heart conditions is encouraging. Slipyan[5] and Goldwater and his associates[6] have demonstrated that even cases of cardiac decompensation have remained employable.[7,8]

TABLE I. PERCENTAGE BREAKDOWN OF MEDICAL DISABILITIES

Cardiovascular diseases	36.2%
Neuromuscular disorders	20.2%
Pulmonary diseases	7.4%
Metabolic diseases	7.1%
Neuropsychiatric disorders	6.4%
Faulty vision	4.7%
Gastrointestional diseases	3.4%
Deafness	2.6%
Obesity	2.5%
Hernia	2.1%
Carcinoma	1.8%
Renal Diseases	1.4%
Dermatitis	1.2%
Other	3.0%
Total	100.0%

TABLE II. CARDIOVASCULAR DISEASES

Angina pectoris and coronary insufficiency	14.5%
Myocardial infarction	20.1%
Rheumatic heart disease	24.5%
Essential hypertension	12.9%
Arteriosclerotic heart disease (failure)	9.7%
Hypertensive heart disease	6.1%
Congenital heart disease	4.0%
Peripheral vascular disease	5.6%
Cerebrovascular accidents	2.1%
Luetic heart disease	0.5%
Total	100.0%

TABLE III. NEUROMUSCULAR DISORDERS

Low back syndrome	27.0%
Operated herniated disc	12.0%
Rheumatoid and degenerative arthritis	13.0%
Poliomyelitis deformities	12.5%
Other deformities	19.0%
Amputees	9.0%
Miscellaneous	7.5%
Total	100.0%

Neuromuscular disorders place second in importance within our facility. Table III gives the distribution. Following a very careful placement evaluation, sometimes with limitations in lifting, climbing, etc., these employees can be expected to perform at full capacity. Due to the high incidence of relapse

in cases of low back syndrome, these employees must be checked regularly. Often, a course of physical rehabilitation is most helpful in strengthening the muscular and ligamentous framework to withstand physical stress while simultaneously keeping the patient ever conscious of his inherent weakness. With the physical deformities, extraneous factors such as travel, parking, toilet facilities, cafeteria, and inplant locomotion must be solved before placing a man at his work station.

Pulmonary disorders comprise 7.4 per cent of the total group of chronically ill. Of these, 53 per cent are cases of inactive or arrested pulmonary tuberculosis and 23 per cent are employees with bronchial asthma. The remaining pulmonary diagnoses are greatly varied. This group must be checked because of their physical environment and the possible strenuous nature of their work. Extremes of temperature, frequent changes in temperature, high altitude, and dusty environment are all to be avoided. They should avoid areas where sensitizing substances might possibly get into the atmosphere. Early arrested cases of pulmonary tuberculosis should be restricted to the regular work schedule, avoiding overtime. Most employees of this group should be followed clinically and by chest x-ray at least once a year.

Metabolic disorders, primarily diabetes mellitus, constitute about 7 per cent of our total group. These people are medically capable of performing most assignments. Diabetics are to be kept out of occupations where there is a high incidence of physical trauma, isolated assignments, or occupations where a mistake might cause physical harm to others. Anyone who requires hypoglycemic medication should not be allowed to drive commercial vehicles or power-operated trucks within the plant. Diabetics should be checked regularly to see that they are maintaining adequate medical control.

Neuropsychiatric disorders comprise about 6.5 per cent of the total group. In this category, 38 per cent of the employees are classified under neuroses that are severe enough to be considered significant and potentially explosive. These people require understanding from everyone concerned, but when followed along with the support given by the family physician or psychiatrist and the medical department most are able to function in their jobs fairly well. When a problem arises, the medical department should be ready to work with the employee, his physician, and management to help remedy the situation. Of course, the severely ill in this group may be unemployable until their condition is under control. Too frequently the psychotics request reinstatement before they have received the maximum psychiatric assistance. Laxity in this regard may be extremely hazardous. Over 30 per cent of the neuropsychiatric group are classified as having convulsive disorders. These people are employable in a wide variety of occupations so long as they cooperate under medical control. This program is followed with the employee and his family physician or neurologist. The restrictions on employment include height, climbing, transportation, certain types of machinery, high-power electrical circuitry, or areas where a fall during a seizure would cause additional dangers.[9]

There are various other major groups of chronic illness that have been found to be employable with only minor changes in an otherwise normal work

routine. Of these, we have a group whose faulty vision is marked enough to fall into this category. These make up about 5 per cent of the handicapped and include the partially and totally blind as well as certain types of color-blind deficiencies.

Gastrointestinal disorders, the majority of which are peptic ulcers, are next in importance. There are usually few restrictions required for people in this group and most do well in any type of work, provided there is job satisfaction and good interpersonal relationship with fellow workers. There may be special considerations necessary where frequent shift changes occur in a department to maintain a proper dietary schedule. In some cases it may be necessary to arrange for between-meal feedings as the recently acute case is being resolved.

The remaining group of our "III MED" classification includes a wide variety of chronically ill in such categories as renal diseases, dermatitis, deafness, and others. These people also may require some adjustments in work assignments but are usually fairly easy to assimilate into the regularly available work classifications.

VOL.
9
195

SUMMARY

Today the industrial physician must adapt a more enlightened view of the physical capacity of the employee or candidate for employment in terms of ability to perform a specific job assignment. Competency need not be measured in terms of anatomic perfection. Similarly, the chronically ill are to be evaluated according to current physiologic and functional concepts of medicine. Although physically or medically disabled, the individual is rarely vocationally handicapped.

Accepting this philosophy it is demonstrated how one company can maintain on its payroll 1,200 employees (or 7.8 per cent of the total work force) who have a serious medical or physical handicap. Every applicant for employment is accepted as potentially employable. This practice of employment of the chronically ill under the strict controls described has proved to be no great hardship in a company that spreads its insurance risks over a reasonably large population.

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THE VALUES AND LIMITATIONS OF PERIODIC HEALTH EXAMINATIONS

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OL.
9
959

PERIODIC health examinations are being increasingly advocated and performed, especially within industry.[1] Is this desirable? Review of some of the background of such examinations and of evidence and opinions concerning their value and limitations may help clarify our thinking on the subject.

Periodic health examinations or evaluations are, as the terms imply, examinations of individuals performed at periodic intervals to determine the status of their health even if they are symptom free and seem to be well.

Such examinations are usually done with the goal of helping those examined retain or even improve their health. When carried out as part of a company's occupational medical program, this may be their goal, or they may be done exclusively or additionally (1) to help assure the continuing fitness of those examined for the duties which they perform, especially when their own safety or that of others depends upon their fitness, and/or (2) to help assure that the health of those examined is not being adversely affected by any potential hazards of their working environment.

There is no purpose in our debating the value of examinations performed when indicated for either of the latter two reasons, assuming that those performing and interpreting them have the skill and judgment required. Whatever may be the limitations of periodic health examinations, it is unlikely that any physician would suggest that the periodic evaluation of the health of airplane pilots or workers exposed to known carcinogens would be without value. Organized medicine has extended its endorsement to such examinations.[2] Let us, therefore, confine our critical discussion of periodic health examinations to those which are performed purely for the purpose of health maintenance or improvement, recognizing that many of the values and limitations we mention would be equally applicable to such examinations no matter what their purpose.

In 1861, Dr. Horace Dobell[3] proposed ". . .that there should be instituted, as a custom, a system of periodical examination, to which all persons should submit themselves, and to which they should submit their children." In the interval between then and now, this proposal has been endorsed by many others.

Barès,[4] writing in France in 1902 on the possible necessity for periodic examinations, enthused about the wealth of knowledge that could be expected

to result from analysis of the observations made in the performance of such examinations.

In the interval between 45 and 30 years ago, physicians in public health work, in the insurance industry, in industry generally, and in the military services, together with others in private practice, attempted to stimulate the widespread performance of periodic examinations for the purpose of health maintenance.

In 1914, S. S. Goldwater,[5] referring to data collected at the Massachusetts General Hospital and at Cornell and to the finding that 62 per cent of 800 New York garment workers examined were in need of medical treatment, wrote: "I, for one, am not willing to cease short of a radical change in the manner of applying medical knowledge. Preventive medicine cannot do its utmost good until physicians are regularly employed by the entire population, not merely for the treatment of acute and advanced disease, but as medical advisers in health." He concluded that: "The next great task of preventive medicine is, therefore, the inauguration of universal periodic medical examinations."

In 1919, Mock[6] summarized his writings of preceding years, and the reports of others, concerning the desirability of such examinations in industry, advocating that: "Every employee, male and female, from the head of the concern down, should be examined."

In 1922, the House of Delegates of the American Medical Association adopted this resolution: "Whereas, the need and value of periodic medical examinations of persons supposedly in health are increasingly appreciated by the public, it is recomended . . .that the county medical societies be encouraged to make public declaration that their members are prepared and ready to conduct such examinations. . ."[7]

In 1923, Roger Lee[8] spoke and wrote impressively about the importance, limitations, and opportunities of periodic health examinations. In 1924, physicians were told that they "must recognize a rising movement among the laity demanding that physicians prepare themselves to make intelligent reports on the physical state of adults who are apparently healthy" and that the time had come for the medical profession to "take up the subject of periodic examinations as one of its major activities."[9]

The next year, the American Medical Association published a manual on the conduct of such examinations.[10] In 1927, Eugene Lyman Fisk, after more than 20 years of experience, study, speaking, and writing on the subject, published, with Crawford, a book on the method of performing periodic examinations.[11] Already at that time—over 30 years ago—his list of references on this subject required 8 pages of print.

Since then, a number of people in our country have sought, and most of them have obtained, periodic examinations from their personal physicians or at clinics or from medical groups that have been more active in their performance. Pediatricians and our dental colleagues especially, and to some extent ophthalmologists, obstetricians, and gynecologists—among others—have for a number of years allotted varying but appreciable portions of their time and efforts to periodic examinations of patients not known to require treatment.

VOL 9 195

Nevertheless, even today, only a relatively small portion of our people, and of physicians themselves, are being examined periodically.[12] Many who champion such examinations would endorse the continuing accuracy of Edie's[13] statement, made in 1925, to the effect that: "The proposal that healthy people be examined at regular intervals . . .is notable for the logic of its theory and the slowness of its adoption" and describing those proposing such examinations as "voices in the wilderness."

We ought, therefore, to review quite critically the evidence for and against such examinations and to consider the factors influencing their value and the performance of them. In doing so, let us first present some of the most frequently expressed criticisms of such examinations and then examine these and some of the evidence and other opinions pertinent to them.

OL.
9
959

COMMON CRITICISMS OF PERIODIC EXAMINATIONS

Perhaps the most common basis for criticism of periodic health examinations is an attitude summarized succinctly by Christ almost 2,000 years ago: "It is not the healthy who need a physician, but they who are sick" (Matthew 9:12).

The physician often points out that he studied medicine to help the sick and that his interest is in sick people and their diseases. He may add, accurately, that he is already entirely busy caring for people who are ill and need his help. He may even summarize his attitude toward such examinations by saying: "I can't think of anything duller than doing a bunch of routine physicals." He often wonders sincerely if any physician doing many such examinations can keep from losing his clinical skill or if these examinations are not usually being done by physicians who already feel themselves inadequate for more dramatic clinical work.

Many physicians feel that examinations of this sort are not worth their while when their total yield is weighed against the time, skill, energy, facilities, and money involved. They believe that a large proportion of the diseases or defects discovered during such examinations are not important. Many, they feel, do not need treatment or even observation, and many others cannot be helped. They express the opinion that most of the diseases or defects found that are of real importance would bring the patients to the doctor eventually anyway and doubt that much is gained by the time "saved."

A great many physicians emphasize the limitations in our ability to measure health with accuracy, often quoting an instance where an individual has died soon after being reassured about his health on the basis of a periodic examination. They take exception to the false sense of security that they feel patients obtain from these examinations. They caution about the frequency with which we may do harm by making those we examine over-anxious concerning their health.

Many physicians are convinced that even if we wished to do such examinations widely at present, we do not have the doctors, nurses, technicians, and facilities needed to do them. They doubt that patients would be willing or able

to spend the money that would have to be charged for a thorough health evaluation. Further, they ask how we could ever convince patients that examinations of this sort are desirable if we cannot even persuade doctors themselves to have them.

Some physicians, observing the performance of periodic health maintenance examinations as part of occupational medical programs, ask why the American businessman, whom they recognize as the champion of free enterprise and fair competition, gives employees these examinations without cost. They point out that in their opinion this is hardly fair competition for the physician who is practicing medicine privately as a free enterprise.

To what extent are these criticisms justified?

DISCUSSION

First, it is generally true, of course, that the sick man needs a physician more than the healthy. The ill cannot go unattended while physicians tend the healthy. But in considering this concept, we must be reasonable. Would we condemn physicians immunizing the still-healthy in the midst of an epidemic as behaving undesirably in failing to devote their attention exclusively to the unfortunates already ill?

Christ, in speaking of the sick man's need for a physician, was likening that need to the sinner's need for His help, and theologians would not interpret His quoted words as meaning that Christ's help would not be available as well to the good man or that the latter were independent of it.

How does a physician know whether or not an individual is healthy without examining him if, to beg a question momentarily, asymptomatic disease is as common as it is claimed to be? Let us admit that the completely healthy individual does not need a physician. Evidence exists, however, to indicate that it requires thorough medical examination to separate those who are in good health from those who believe themselves to be in good health but in fact are not. Reports indicate, at least with respect to the adult male, that thorough examination will usually reveal that actually only 10 to 25 per cent of those who seem healthy are quite entirely healthy and that from 25 to 35 per cent of those being examined for the first time will be found to have some significant disease which was not previously known to exist.[14-22]

With reference to why most physicians seem to lack interest in the performance of periodic health maintenance examinations, one of the most commonly expressed reasons is the doubt that the examinations require sufficient skill to be challenging or offer sufficient opportunity to earn the satisfactions sought by physicians in the practice of medicine. Of course, such doubts alone could not justifiably dissuade a physician from performing these examinations if, his goal being the patients' welfare, it could be demonstrated to him that the examinations can contribute appreciably to the maintenance or improvement of his patients' health.

If evidence exists that a patient's prognosis is better if his malignancy is diagnosed early, it becomes difficult, of course, to try to weigh the accomplishment of a physician who examines many people to find a single early asympto-

matic malignancy against the accomplishment of his professional colleague who, dealing with sick people over the same time interval, diagnoses and treats 2 or 3 well-along symptomatic malignancies.

Physicians daily reaping the satisfaction that results from the immediate and obvious expressions of gratitude by patients and their families for efforts in their behalf at a time of rather dramatic need might not find very appealing the prospect of trading this for satisfactions that must often be derived interiorly and can be enjoyed only in smaller doses at less frequent intervals. Here again, however, if it could be demonstrated to them that their patients' prognoses would be better, perhaps they could be convinced that their eventual net income, satisfaction-wise, would be great indeed.

Does it require less skill to do periodic health examinations than to handle sick patients? Need the performance of "routine physicals" be boring?* Ought they to be relegated to physicians who, with or without justification, lack confidence in themselves? These questions do not lend themselves to exact measurements. However, some opinions pertinent to them merit attention.

Although any physician who approaches and performs periodic examinations "routinely" in the unsavory connotation of that adverb will undoubtedly be bored, some might be challenged would they but contemplate seriously the possibility that it may require more skill and more knowledge of health and normalcy as well as of disease to recognize an early stage of a disorder than it does to recognize a later stage of the same disorder. Although less skill might be needed for the effective treatment of early disease, this still could be sufficiently challenging to be satisfying, and the patient and his family would not be disappointed if his illness could be treated successfully with less than maximum skill.

In 1861, Dobell[3] wrote ". . . the manner in which man is to exercise his instrumentality for the prevention of disease, the prevention of the vestiges of disease, and the prevention of fatality in disease, is to search out those earliest evasive periods of defect in the physiological state, and to adopt measures for their remedy. *This appears to me to be the highest, the most enobled duty of the physician, calling for the most abstruse knowledge of the science of life, the deepest experience in disease, the keenest exercise of the perceptive faculties, the calmest, most far-sighted reasoning, and the wisest judgment—a duty as much above the management of acute disease as to rule an empire is above fighting a pitched battle.*"

In 1942, an outstanding clinician serving as Professor of Medicine in one of America's finest medical schools wrote ". . . the public must be taught not only that *a periodic health examination* is a valuable investment for better health, but that it *is perhaps of all tasks the doctor is asked to perform, the one that calls for the greatest skill and wisdom.*"[23]

*The word "physical," if used to refer to an attempt at measuring an individual's health, is an unsatisfactory designation in many ways, and physicians should cease to use it in this fashion. The physical examination is but one step in the evaluation of a person's health, and to exclude from any examination the obtaining of any information or the making of any observations about elements of health that are not physical is unrealistic. Examinations should be referred to as medical or health examinations, except when we refer specifically to that part of an examination which deals as exclusively as it can with the patient's physical status.

But in 1958 several keen young medical students, soon to graduate with an impressive amount of knowledge from this same medical school, told me that their interest is in clinical medicine and that they hope to be real clinicians and cannot possibly imagine themselves being interested in examining people who seem to be well.

It is evident that both undergraduate and postgraduate medical education today are oriented so heavily toward the ill patient and his disease that those attempting to focus the attention of future physicians on health and well people have little success. They do, of course, interest some students, but relatively few in a deep and lasting fashion. We must, therefore, add to the criticisms of periodic examinations already listed the doubt that most of us, as physicians, are adequately prepared, either in orientation or by training, to do such examinations. Further, we must also face the fact that we do not seem to be adequately preparing medical students to do them in spite of the efforts of many teachers who are sincerely convinced of the desirability of this goal. Illustrative of the limited progress being made is the likelihood that relatively few of the students graduating as physicians this year have ever had a really thorough evaluation of their own health.

Many physicians whose only clinical work is the periodic examination of supposedly well people have concluded that, as has been suggested, it is truly difficult to maintain clinical skill if such work is one's exclusive clinical activity. The clinician who has accumulated and can retain easily a splendid fundamental knowledge of health and disease, who is possessed of an inquiring and analytical mind, and who uses it might thrive and progress through many years of doing such examinations alone. But, unfortunately, most of us do not have this capacity, and we need the assistance of continuing contacts and study to maintain our knowledge and acuity about things infrequently encountered. Rigler,[24] in a fine discussion of one type of periodic examination, cautions about "the psychology of the negative," the negative-mindedness that is risked. This is a matter to which doctors doing health maintenance examinations quite exclusively must consistently and regularly give attention, and which will in most cases require adherence to a program of planned medical reading, study, and periodic contacts with professional colleagues, medical teaching environments, and broader clinical horizons.

To discuss the relationship of the yield of periodic health maintenance examinations to their "cost" in terms of the time, energy, and patience of those examined, and the money, and the technical and professional time, energy, skill, facilities, equipment, and material involved, we must ask what the yield has generally been from the performance of such examinations.

As has been pointed out, and it seems to be true, such yields would be expected to vary in the sexes, with age, race, location, socioeconomic, and other factors, with the caliber and thoroughness of the examinations and examiners, the cooperation of the examinees, and the effectiveness of follow-up observation and treatment.[25] In spite of this, when we review what various physicians over the past 45 years have reported as their findings when they examine groups of supposedly well individuals, most of whom have admittedly been adult males,

VOL 9 195

there is an impressive consistency with which at least 15 per cent and up to 40 per cent of those examined are found to have a significant disease or defect of which they are unaware. In as many as one-half to two-thirds of the cases, these disorders are still asymptomatic when so discovered. Further, in a like number of those examined (15 to 40 per cent) there is usually found some known disease or defect for which only about half are obtaining indicated treatment or medical observation.[5,10,14-22,25] Most who report on this subject classify as "significant" any disease or defect able or likely to shorten life or result in some incapacity or disability.

The disorders most frequently diagnosed in adults at the time of initial or subsequent periodic examinations are shown in Table I,[14-22,26-30] the variations in frequency being influenced by differences in the scope of examinations performed, interests and training of the physicians performing them, age distribution in the groups examined, diagnostic criteria, etc.:

TABLE I

DISEASE OR DEFECT	PERCENTAGE INCIDENCE AMONG THOSE EXAMINED
Obesity	10 to 30
Arthritis, rheumatism	10 to 20
Hypertensive disease	5 to 20
Arteriosclerotic heart disease	5 to 20
Hemorrhoids	5 to 20
Anxiety state	5 to 20
Rectal or sigmoid polyp or adenoma	5 to 15
Vasomotor rhinitis	5 to 15
Peptic ulceration	5 to 10
Inguinal hernia	5 to 10
Anemias	5 to 10
Cholelithiasis	4 to 7
Nodular goiter	2 to 5
Diabetes mellitus	1 to 3
Renal calculus	1 to 2
Glaucoma	1 to 2

In varying but appreciable incidence the following are encountered:

Visual acuity defects	Colonic diverticula
Benign prostatic hypertrophy	Skin lesions
Varicose veins	Hiatal hernia
Hydrocele, varicocele	Gout

Occasional cases of the following are discovered:

Congenital heart disease	Carcinoma of the breast
Rheumatic heart disease	Carcinoma of the rectum
Active pulmonary tuberculosis	Carcinoma of the cervix
Carcinoma of the skin	Carcinoma of the lung
Carcinoma of the colon	Carcinoma of the thyroid
Carcinoma of the stomach	Carcinoma of the larynx
Carcinoma of the prostate	Lymphomas and other malignancies

Observing the occasionally great variations in the reported incidence of a specific disease in different groups examined, we may either be tempted to doubt the accuracy of the observations or be understandably confused about factors that could explain such variance. For example, while Densen, D'Alonzo, and Munn[31] report no diabetes mellitus whatsoever among the employees in 10 different plants with a total population of at least 3,000 individuals, Tupper and Beckett[29] report 37 definite cases and 31 suspected cases of diabetes amongst 294 University of Michigan faculty members. Unless patients with diabetes are excluded from employment in the plants studied by the former authors and preferentially are selected for employment, or inbred, at Michigan, it is difficult to understand the difference in incidence of this disease in these two groups and the difference between its incidence in each group and that usually reported in the general population. No practically imaginable divergence of diagnostic criteria could explain differences of this degree.

Reviewing the reported findings on periodic examinations, any of us would be tempted to challenge the justification for labeling certain of them as significant, especially in view of the infrequency with which they are demonstrated to produce disability or shorten life. Admittedly, too, with respect to many findings that obviously are significant, we would have to acknowledge our complete or relative ineffectiveness at the present time in altering the course of the patient's disease.

We must face frankly the areas in which we are thus far completely frustrated. We are entitled to be disappointed, but we are not, of course, entitled to be discouraged. Although, for example, we must admit that the majority of patients with primary carcinoma of the lung may not be saved by present-day treatment received even before their initial symptoms appear, it does seem, as will be illustrated, that at least a few extra patients in each hundred treated while still asymptomatic do survive in spite of the limitations in our effectiveness.

MacDonald and Kotin[32] have pointed out that their studies caused them to conclude that "the concept that the early diagnosis of carcinoma of the stomach may improve the end results is not only fallacious but is in fact the reverse of the truth." Although in support of their conclusion they could point to higher survival rates in patients with carcinoma of the stomach whose symptoms were of longer duration and to lower survival rates in those whose symptoms were of shorter duration, the conclusion itself would appear unjustified. The very important point that these two workers emphasize—the extent to which a specific tumor's nature predetermines significantly the patient's possibilities of survival—worked, it would seem likely, to select into the groups with symptoms of short duration those patients with highly anaplastic, fast-growing, and early-metastasizing tumors and into the other groups those with more differentiated, slowly-growing, and late-metastasizing carcinomas. They do not present, and we do not know of, any real evidence that patients whose carcinomas of the stomach are diagnosed and treated early fare less well than those with comparably anaplastic or differentiated carcinomas diagnosed and treated later in the course of the disease.

While some may be awed, and we must all be impressed, by the extent to which in many malignancies the patient's destiny seems so much predetermined by the nature of his tumor and by his own susceptibility to it, we must continue to attempt the earliest practical recognition and treatment of such lesions.

Happily, there are relatively bright areas. Even those who feel that the threat of carcinoma in situ is being exaggerated can hardly fail to be impressed by the limited but accumulating evidence of more favorable survival rates in those who receive treatment for certain types of carcinoma in the earlier states of their disease, especially while still asymptomatic. Survival rates in patients with carcinoma of the stomach, colon, rectum, larynx, breast, and uterus, and even in patients with carcinoma of the lung, as pointed out before, do seem better when the disease is treated early, in spite of some of the scepticism that has been voiced.

Robbins and Bross[33] have pointed out the significance of delay with respect to patients having carcinoma of the breast. Boucot and Sokoloff[34] report 20 per cent of their patients with asymptomatic carcinoma of the lung surviving 3 years or longer, as opposed to the rate of 9 per cent among those with symptoms. Overholt, Bougas, and Woods[35] report 3-year survival rates of 30 per cent as opposed to 12 per cent, and Davis, Peabody, and Katz[36] report the survival for 2 years or longer of 52 per cent of patients without symptoms as opposed to 14 per cent of those having symptoms. The latter authors point out that, of 14 patients with small, solitary, circumscribed, asymptomatic bronchial carcinomas operated upon 5 or more years ago, 11 (78 per cent) are still alive and well.

Hufford and Burns[37] report that 5-year follow-up studies revealed only 2 of 22 patients with asymptomatic carcinoma of the uterus had died of carcinoma, whereas 22 of 41 patients with symptomatic carcinoma had died over the same interval. Hitchcock and Aust[38] report 17 of 18 patients with asymptomatic carcinoma of the colon and rectum well up to 5 years after the time of diagnosis, whereas only 3 of 8 patients with symptoms still survive. Six out of 9 of their patients with asymptomatic carcinoma of the stomach were alive up to 5½ years after diagnosis, whereas only 1 of 5 patients with symptomatic gastric carcinoma survived.

While these quoted experiences deal in some instances with small or relatively small numbers of cases and in others with too-short (even though comparable) periods of observation, the same general trend in the large amount of data available to the American Cancer Society and the National Cancer Institute has caused the Joint Committee on Cancer Statistics of these two groups to concur in some interesting pertinent estimates shown in Table II. If we grant that localized carcinoma should be "earlier" carcinoma, the extent that it is "earlier" admittedly varying widely with the nature of the tumor and other factors, these estimates give us some clue to possible benefits that might be derived from the combination of earlier diagnosis and good treatment.

Lest it be felt that too much emphasis is being placed upon the possibility of the earlier diagnosis of malignancy influencing survival rates, we need only consider the fact that present data indicate that in our country 1 out of 4 people develop a malignancy at some time during their life.[1]

TABLE II. PRESENT AND POTENTIAL 5-YEAR SURVIVAL RATES FOR PATIENTS WITH MALIGNANCIES[39]

SITE OF MALIGNANCY	PER CENT OF PATIENTS PRESENTLY SURVIVING 5 YEARS*	PER CENT OF PATIENTS THAT COULD POSSIBLY SURVIVE 5 YEARS OR MORE WERE TUMOR DISCOVERED AND TREATED IN LOCALIZED STAGE†
Tongue	17	68
Esophagus	2	3
Stomach	6	48
Colon	29	50
Rectum	25	77
Larynx	37	64
Lung	4	34
Breast	46	81
Cervix	53	69
Body of uterus	62	78
Ovary	24	48
Prostate	21	32

*Based on Connecticut experience; cases diagnosed 1947-1951.

†Based on experience of specialists reporting at the Third National Cancer Conference; cases diagnosed 1946-1950.

Adapted from tabular material contained in Minutes of the July 26, 1956, meeting of the Joint Committee on Cancer Statistics of the American Cancer Society and the National Cancer Institute.

With respect to diseases other than malignancies, we know beyond doubt that treatment can help at least a portion of the patients with some of the diseases encountered relatively commonly, such as hypertension or diabetes. It may seem prematurely optimistic to suggest that patients in whom coronary atherosclerosis is recognized early will be in a position to be helped appreciably, but nonetheless this is the impression of many.

Unfortunately, although we have many reports telling us what asymptomatic disorders can be found by periodic examinations, we have few that include follow-up studies that enable us to compare the ease or success of treating patients whose disease is so discovered with that of treating comparable patients in whom comparable disease is discovered after and because it becomes symptomatic. We have little evidence of the frequency with which patients seek and obtain the care or observation advised and with what results.

Whalen and Woodward,[40] studying what happened in the cases of 100 patients in whom a significant new diagnosis was made at the time of periodic examination, found that 68 per cent promptly sought and obtained the care or observation needed. Fifteen per cent delayed from one to several months but eventually sought and obtained it; 11 per cent promptly sought it but obtained it only after delay. Six per cent of the patients could never be persuaded to seek or accept treatment, including one with a carcinoma.

Prickman and his associates[22] studied the extent to which 231 executives having at least two periodic health maintenance examinations at the Mayo Clinic complied with medical and surgical advice. They found that 65 per cent complied fully, 18 per cent not at all, and the balance partially, for example, accepting care for a medical problem but declining recommended surgery. They

noted a slightly greater tendency for patients to comply with advice given after a second or third examination than with that given after an initial visit.

Mitchell,[26] reporting in 1943 on 1,580 individuals examined two or more times, indicated the frequency with which defects discovered at initial examination had been eliminated by the time of follow-up examination. For example, he noted that only 9.7 per cent of those obese at the time of their first examination were no longer obese when re-examined. Only 19 per cent of those having inguinal hernias had had them corrected by the time of subsequent examination. Thus we note that the discovery of such disorders is very often not followed by successful treatment, even if good treatment is available.

Baker and his associates,[41] re-examining 106 people found to be obese at the time of previous examination, found that 15 per cent were no longer so when re-examined, 34 per cent had improved, 40 per cent were unchanged, and 11 per cent were worse. The same workers reported cure or improvement of 83 per cent of the patients in whom anemias were diagnosed, cure or improvement in 31 per cent of those with hypertensive vascular disease, and improvement in 20 per cent of those with hypertensive cardiovascular disease.

Franco[17] reported that follow-up studies of the diseases found in 707 patients over a 7-year interval revealed 20 per cent of his patients had been cured, 33 per cent were improved, 31 per cent were unchanged, and the balance were worse (8 per cent), retired as disabled (3 per cent), or dead (5 per cent). He indicates, however, that only 35 per cent of the patients with asymptomatic disease were cured or improved, whereas 68 per cent of patients with symptomatic disease were cured or improved. Such results would seem truly disappointing to the advocates of the early detection of disease. However, the different results in these groups may well have been far more influenced by differences in the nature of findings in the two groups than by whether the patients had symptoms or not.

It is true, of course, that even in the best of hands periodic health evaluation may fail to detect life-threatening disease, as, for example, the reported failure of one group to detect 9.4 per cent of the malignancies occurring in the patients studied by them, about half of these being frankly missed and the other half undiagnosed because of a lack of patient cooperation.[38] Guiss[42] reports the death of 27 individuals from carcinoma of the lung within a year of the time that 70 mm. screening films of their chests failed to reveal evidence of such a tumor, although it should be noted that, on the positive side, the same screening program resulted in the finding of 213 other cases.

Most physicians have had the sad experience of seeing a patient die soon after an examination which revealed no threat to his life. Most commonly, such episodes have been related to our inability to demonstrate coronary atherosclerosis with consistency. But so long as we face such limitations and work to eliminate them as completely as we are able to practically, this need not be discouraging when weighed against what can be accomplished.

Care must be taken, of course, to assure so far as possible that patients do not obtain an unjustified sense of security on the basis of an essentially negative health examination. It is true that those examined are sometimes un-

qualifiedly assured of the excellence of their health after grossly inadequate examinations. In view of the recognized inadequacies in even the best of examinations, we advise that patients always be told something of the limitations in our ability to measure and predict health and that they be cautioned to seek assistence promptly for any new, recurring, or persistent symptoms that trouble them between scheduled periodic examinations. The necessity of doing this, if it is done properly, need not deprive patients of the satisfaction of being reassured in general concerning the status of their health, if such reassurance is justified, nor need it cause them to become overanxious or hypochondriacal. My associates and I, who believe ourselves sensitive to these possible complications, seldom indeed encounter evidence of a patient having suffered any ill effects traceable to an unjustified sense of security resulting from such an examination. Nor do we often see a patient become overanxious about his health upon the basis of one. Both hazards do admittedly exist, and probably the fact that we consistently and conscientiously guard against them explains the infrequency with which we see them. From the positive viewpoint, it is worth noting that we are very often able to allay a patient's anxiety about his health following an examination which reveals no justification for such anxiety.

With reference to the concept that at present we do not have sufficient physicians, nurses, technicians, and facilities to examine everyone periodically, it can only be admitted that this is unfortunately true. Some feel, however, that quantities of these "sine qua nons" might be freed for such work if the ill, who now require so much of their energy and time and space, could be treated much earlier in the course of their disease so that their treatment could be, at least in some instances, more simply and promptly accomplished.

Admittedly, if all the general practitioners and internists in our country were sufficiently free and interested now to examine 3 or 4 people thoroughly each of their working days, this still would not suffice for annual health evaluation for all of our adults. But if each such physician examined only 1 to 2 patients daily, each could be offering 500 patients annual or biannual health maintenance evaluations. This itself might diminish the need of this segment of their patient population for more time-demanding care and might permit a gradual shifting of the emphasis in their practice toward more preventive health maintenance work and earlier therapy.

Basically it seems evident, however, that, for thorough health maintenance service to be widely available at the same time that patients needing therapy can obtain the optimum amount and quality of care, and for necessary medical research, teaching, and public health work to be accomplished, we do need more doctors, especially more good general practitioners and internists whose services are available to the public.

When we come to the question of the willingness and ability of people to pay the necessary cost of thorough health maintenance services, we can only point out that many have already evidenced their willingness to do so and express our conviction that many others, even if not all, can be educated to be willing.

Rutherford and Banks[43] reported recently that when they offered their patients, without particular enthusiasm, the opportunity to revisit them periodically for examination even in the absence of symptoms, the number of visits made by patients for this purpose soon became so large that they were forced to restrict them in order to continue their regular practice. Fremont-Smith[44] says that on the basis of 40 years' experience he has learned well that people will pay for a thorough examination and will return for others year after year.

That education can stimulate people to accept such examinations and respect their value is evidenced by the continuing and growing percentage of employed individuals who voluntarily have them periodically when they are offered. Under these circumstances, they are usually without cost to the employee, which is a factor of importance. However, in our experience, almost 60 per cent of those participating in our program continue to seek such examinations from their personal physicians after they retire when they themselves must pay for them out of their reduced retirement income.

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959

In most instances, two basic considerations have undoubtedly encouraged the acceptability of these examinations to employees. First, wherever their own safety or that of others does not depend upon their fitness, the examinations have usually been offered rather than required and participation in the health maintenance program has been on a voluntary basis. In some well-established programs, as many as 90 to 100 per cent of those eligible have participated.[28]

Second, but of singular importance, has been the assurance the employee has had that results of the examination will be treated confidentially and not revealed to anyone except at his request. It is perfectly evident that the value of periodic examinations is distinctly limited whenever the individual being examined cannot be assured that information learned about him in the course of the examination will be kept confidential.

It is clear that both of these factors, the voluntary and the confidential nature of the program, are important in encouraging the complete and frank cooperation of those participating. An additional criticism of periodic examinations performed in industry has been based upon the possibility or likelihood that the patient will not give a frankly honest health history either because he is being examined involuntarily or because he lacks conviction that information learned about him will be treated confidentially and not used against his interests. In our experience, however, even those employees required by the nature of their work to have examinations have usually participated unreservedly upon recognition of the goals of the examination and upon demonstration over the years of the confidential and ethical nature of the patient-physician relationship involved.

It is truly a biting indictment that it has not been possible to persuade most physicians to have health maintenance examinations themselves periodically. This, however, seems primarily a matter of education—a failure in communication. Unfortunately, a great proportion of physicians are not only unacquainted with the facts concerning such examinations but are even more inclined than the laity to dismiss them without interest or with comments more emotional than scientific. Unreasonable as it may seem, fear of what might be

discovered is probably as often the reason a physician avoids examination as it is the layman's for doing so. This attitude is compatible with the observation[45] that there is essentially just as much delay in the diagnosis and treatment of malignancies among physicians as there is among the laity.

While the cost of such examinations carefully performed is appreciable, we do not believe ourselves entitled to assume that it is beyond the capacity of a great portion of our population to budget for them. When we weigh the potential importance of these examinations against that of innumerable other expenditures regularly made without great resistance, we cannot doubt that education on the matter and good judgment might inspire many people to provide such examinations for themselves and their families, especially if we are imaginative enough to design and offer practical and ethical plans to prepay for their cost. Further, with the efficiencies and economies that can be realized, the cost of these examinations need not be as high as many are publicized to be. Some groups in private practice already include them in services offered on a prepayment basis at a cost that a good number of people of modest socioeconomic level are paying.

Why should these examinations be offered employees by their employer without cost? The reason seems to be that the employer has been persuaded that they help assure him of an effective, productive work force and hence help assure the success of his business. Were his employees seeking and obtaining health maintenance services from their personal physicians, the employer might have little incentive to do more than assure his employees' fitness for their work and freedom from undesirable effects of their work environment. These latter assurances must often be obtained from a physician who is a specialist in occupational medicine because they require a familiarity with the worker's duties and with the often-complex physical and psychologic aspects of his working environment. Inasmuch as the private practitioner cannot be expected to gain and retain the specialized knowledge and competence required for this and some other work in this field, we shall continue to have occupational medicine as a specialty.

It does seem, however, that most employers who are providing their employees with periodic health evaluations solely for the purpose of helping them maintain or improve their health are doing so only because they feel the examinations are desirable and will not often be done, or done with interest and thoroughness, unless they provide them.

Where these examinations are performed as part of a company's occupational medical service, they are not, and in our opinion should not be, offered to an employee as a fringe benefit or as a form of compensation in lieu of cash. They are but one of many steps taken and one of many investments made to help assure a company's success. Fortunately, the employee's welfare and the company's welfare are both best served by his remaining healthy, and his welfare is quite obviously even more immediately served than is the company's by steps taken to help him preserve his health.

Where services that include periodic examinations are paid for entirely from union funds, the situation is different, of course, in that under these circumstances

the employee is spending for such an examination money which he has earned but which has been set aside for this purpose under a program arranged for him by his union.

SCOPE OF THE PERIODIC EXAMINATION

What should be included in a good examination designed to evaluate an individual's health? Wade[46] defines health as the optimal adjustment of the total person—physical, mental, social, and spiritual—to his total environment—microbes, automobiles, ideas, etc. Accepting this definition, we would desire a good health evaluation to include a measurement or determination of these adjustments. It would require, to be complete, the taking of a good health history, the making of a good physical examination, and the performing of certain supplementary laboratory and x-ray studies, all planned with attention to the adjustments listed, and would require as well the satisfactory recording, analysis, and communication of the results of the examination to the patient and usually to one or more physicians unless the examination has been done by the patient's personal physician. Although Fisk[47] pointed out over 30 years ago that it is idle to set up standards for these examinations which are beyond what the general practitioner can attain, it would seem best to describe what appears to be desirable regardless of the practical obstacles which might necessitate compromise under some circumstances.

The health history should, of course, be a complete one, although in health maintenance examinations it does not so often contribute to the discovery of a disease or defect as do the physical examination or supplementary studies.[14,18,27] For those accustomed to handling ill patients in contradistinction to the supposedly well, it comes as somewhat of a shock to realize that the history they prize so much seems less productive than the other elements of the examination. However, when we pause to consider the frequency with which diseases discovered during such examinations are still asymptomatic, this is exactly what we should expect. There remain, however, many diagnoses and important observations that can be made only on the basis of a thorough and carefully taken history.

While there is no satisfactory substitute for a careful interview of the patient to develop needed details concerning a complaint or illness, we find that a very thorough health questionnaire completed by the patient in advance of a health maintenance examination contributes greatly to the effective use of the time he and the physician can spend together for a history interview and assures a thoroughness, as demonstrated by the Cornell group,[48] that is not achieved without it.* The use of such a questionnaire to shorten the amount of time that the physician must allot to the examination is one evident manner in which the cost of such examinations might be reduced.

My associates and I, who prided ourselves on our ability to take good and complete medical histories, find that in up to 15 per cent of the patients we see the complete health questionnaire which we use at present elicits potentially

*I would be happy to forward a sample of the health questionnaire used to those requesting one.

significant health history information that we doubt we would have elicited by the interview techniques in which we had so much confidence before designing and using our health questionnaire.

After the patient has completed the questionnaire, it is our procedure, before going on with the physical examination, to interview him in the indicated degree of detail concerning all of his responses that are not negative and to discuss with him a number of health-related matters not adequately covered by the questionnaire.

In addition to eliciting current and past information concerning the patient's organic health, family history, and occupational history, we interrogate him tactfully but in detail concerning his relationships with others, the strains and satisfactions in his work life and family life, his sense of values and his goals, his anxieties, his reactions to frustrations, and his health-related interests, activities, and habits. We also attempt to assess his maturity, his sense of responsibility, and his acceptance of reality.

The physical examination must, of course, be done carefully and completely. We hear occasionally of so-called examinations for which the patient is not asked to undress. We see the frequent omission of such a relatively simple step as the testing of visual acuity. Distressingly, we note the infrequency with which a digital examination of the rectum is included. Such examinations are not adequate ones. As a matter of fact, there is no excuse for short-cutting in health maintenance physical examinations. The ocular fundi should be as carefully explored, the thyroid as carefully palpated, the spleen, lymph nodes, and peripheral arterial pulsations as carefully felt for as they would be in any obviously ill person. A basic neurologic survey should be included.

Although it is not usually described as part of the physical examination, we feel that a proctosigmoidoscopic examination should be included. With good preparation of the patient made so simple today by the use of the disposable enema, with the examination itself so simple that any physician can learn to do it (perhaps with some of the less adept or courageous limiting themselves to the 7-inch instrument), and with the positive findings upon such examinations so consistently high, it seems evident that an examination of this sort ought to be included in a physical survey far more consistently than it is. Time-consuming, yes. Awkward and undignified, yes. Initial reluctance on the part of the patient, yes. But under many circumstances, all of these problems can be surmounted. It need not be pointed out that a health maintenance examination of the female remains sadly incomplete until a pelvic examination has been performed.

With respect to the laboratory and x-ray studies that should be included regularly, a urinalysis, hematocrit or hemoglobin determination and a scanning of a stained blood smear, and an x-ray examination of the chest would seem quite consistently indicated. In some groups, or in some locations, or at varying intervals, other tests might always or occasionally be done. Any tests indicated by any symptom or sign should be obtained.

In females, especially those over 35, a cervical smear for cytologic study ought to become routine. In men over 35 or 40 and women over 45 or 50, elec-

VOL 9 195

trocardiography might well be done regularly, whereas in younger patients only a base line tracing and relatively infrequent repeat studies might be deemed required in the patient whose initial tracing is normal.

In some areas, the stool should regularly be examined for ova and parasites. In certain groups or areas, regular serologic testing for syphilis would be indicated, whereas under other circumstances this might be done less frequently with little risk. Some examinations might be done once, and seldom, if ever, repeated without indication—for example, an x-ray examination of the gall bladder at the age of 45 or 50. Other studies, such as a complete blood count or determination of the serum cholesterol level or of blood glucose following the ingestion of a test amount of sugar, might be done intermittently. Some might desire to use the erythrocyte sedimentation rate regularly.

In those middle-aged or over, intermittently ascertaining the presence or absence of free hydrochloric acid in the stomach by a "tubeless" gastric analysis and at each examination testing the stool for occult blood with an agent of appropriate sensitivity or insensitivity would allow the recognition of some patients in whom gastrointestinal x-ray studies would be justified. We hesitate to advocate x-ray studies without some justification but would feel, for example, that the potential yield in so examining an older man with achlorhydria or definite occult blood in the stool would outweigh the undesirable effects of the radiation involved. We do not, of course, advocate x-ray examination of the abdomen of the fertile female or of the genital area of the male without some indication for it. Indicated but elective x-rays of the abdomen are postponed in women until the cessation of a menstrual period in order that we might have this degree of assurance that the patient is not pregnant.

An obvious consideration with reference to these supplementary studies is the accuracy of the laboratory and x-ray services available, as illustrated by Bolt, Mallery, and Tupper,[49] and Hitchcock and Aust,[38] among others.

The frequency with which a few commonly performed supplementary laboratory and x-ray studies may be "positive" in the supposedly healthy is illustrated in Table III.

The basic examination described will require from 45 to 90 minutes of the physician's time, the amount being influenced by the patient's health problems or freedom from them and by the physician's thoroughness, pace, and working habits. The patient would have to invest from 90 to 150 minutes, including the time required for the completion of the health questionnaire in advance.

After the examination, what? It is impressive to read of how much can be found on periodic health maintenance examination, but the findings are relatively meaningless unless the follow-up procedures assure that diseases and defects that are found receive the medical care or observation required. We feel that the best way to communicate the results of an examination to a patient* is to schedule him for a 15 to 30-minute revisit with the physician, usually several days later following completion and interpretation of laboratory and x-ray studies. During this visit, an attempt is made to tell the patient in terms he

*We ought to have a better designation for the supposedly healthy examinee than "patient."

TABLE III. RESULTS OF "ROUTINE" USE OF CERTAIN EXAMINATIONS

EXAMINATION	PER CENT "ABNORMAL"
Urine for sugar	2.6
Urine for protein	2.2
Blood for hemoglobin	6.7
Blood for sugar	4.1
Blood for syphilis	5.6
Stool for occult blood	15.7
Electrocardiogram	11.9
Cytologic study of cervical smear	0.49 (asymptomatic carcinoma)
Proctosigmoidoscopy	0.3 (asymptomatic carcinoma)
Proctosigmoidoscopy	8.2 (asymptomatic polyps or adenomata)
Chest x-ray	2.88 (abnormality of some type)
Chest x-ray	0.16 (active pulmonary tuberculosis)
Chest x-ray	0.72 (abnormal cardiovascular silhouette)
Chest x-ray	0.01 (primary pulmonary malignancy)

These figures are derived from reports of screening and periodic-type examinations summarized in *The Early Detection and Prevention of Disease*, edited by John P. Hubbard, New York, 1957, McGraw-Hill Book Company, Inc.

VOL. 9 195

will understand what has been found in the course of his examination and its meaning to him. We not only encourage him to ask but attempt to extract from him any and all questions that might come to his mind. As indicated earlier, through all of this we guard as religiously as possible against precipitating anxiety in the patient.

If the patient has any disease or defect requiring treatment or observation and has been examined by someone other than his personal physician, he should be referred at once to the latter, to whom a copy of the record of the examination should be forwarded—but not carried by the patient. As pointed out earlier, all patients do not seek or obtain promptly the treatment or observation needed, so that some provision should be made to remind or reurge those patients that require such to obtain it. Unfortunately, some patients who visit their physicians promptly to seek indicated treatment or observation do not succeed in obtaining it, sometimes because the physician they consult is unimpressed with their still early and mild disease and suggests to them that they ignore it unless or until it becomes more of a problem.

To realize the full potential benefits of periodic health examinations performed in industry, it is necessary that a formula be found and followed to assure cooperation and understanding between occupational health service physicians and the private physicians of employees examined.

FREQUENCY OF PERIODIC EXAMINATIONS

How often should periodic examinations be performed? Reports indicate that examinations subsequent to the initial one yield enough to justify their regular performance, for example, at annual intervals. As would be expected, the more frequent the examinations, the lower will be the yield in new findings. However, in the experience of some, the yield on annual examinations seems sufficient to justify their repetition that often. Bolt, Tupper, and Mallery[15]

discovered new significant disease in from 13 to 20 per cent of those having examinations subsequent to an initial one; Elsom, Spoont, and Potter[18] found the same in 22 per cent of 150 patients re-examined one to two years after their first examination. Hitchcock and Aust[38] report that 45 per cent of 147 malignancies discovered by their group over a 6½ year period in 6,754 individuals were found at the time of re-examination rather than at the time of initial examination.

Specific findings or circumstances in the case of an individual may sometimes indicate examination even more frequently than once yearly. On the other hand, while in our experience the yield at the time of initial examination of younger individuals is quantitatively (although not qualitatively) roughly the same as that in older individuals, there does seem to be a lower yield when younger people are examined each year. For this reason, many have adopted the practice of examining younger patients less frequently—for example, those under 30 years old only every third year, those between 30 and 40 every second year, and only those 40 or over every year.

Rather than permit younger people to go as long as 3 or more years without examination of any sort, it would seem to us preferable to examine them annually but to perform briefer examinations, perhaps largely of a screening sort, in the intervals between more thorough examinations every second or third year.

The limitations of multiphasic screening types of examinations are well recognized, but they can be of distinct and measurable usefulness if they are understood and interpreted properly. Profiting by what has been demonstrated with respect to such examinations, it might be suggested that in interval years between thorough examinations the patient could complete a health questionnaire, have certain basic observations about his health recorded by a nurse, such as his height, weight, temperature, pulse rate, blood pressure, and general appearance, have a few basic laboratory tests including chest x-ray performed, and be seen only very briefly by the physician, or, if necessary, not at all unless something in his responses to the questionnaire, the nurse's observations, the x-ray examination, or other tests reveals the desirability of a physician's attention. Used between more thorough ones, an examination such as this, preferably with at least a brief interview and examination by the physician after completion of the "screening" and without a revisit unless indicated, might at least for the present serve as a practical adjustment to the shortage of medical, nursing, and technical personnel previously discussed and to the expensiveness of annual thorough examinations.

With further respect to the frequency of health maintenance examinations, it seems to have been well demonstrated that the incidence of most diseases is no greater in executives than in other employees, so there does not seem to be need for more frequent examination of the executive group.[21,30,50,51]

Last, with reference to the frequency of periodic examinations, it is self-evident that the physician should be guided in the individual case by his findings upon examination of the patient concerned, especially with respect to indications for more-frequent-than-usual examinations and with respect to special problems created by the patient's environment at work or otherwise.

SUMMARY AND CONCLUSIONS

Attempting to view periodic health maintenance examinations in proper perspective, the following conclusions would seem justified:

With Respect to Their Limitations.—

Periodic examinations are not the keystone of preventive medicine, as they were identified to be in the title of a recent roundtable discussion on the subject. There are many other activities that come under the heading of preventive medicine, such as public health services, that more consistently and very importantly contribute to our health. As Sir Adolphe Abrahams[52] has pointed out, many things that we do every day or could be doing are more capable of influencing our health favorably than are periodic examinations.

Many of the criticisms of such examinations, as listed and discussed, are justified to varying degrees and in varying circumstances and frequency.

We have enjoyed relatively little success in "selling" them thus far to the public or our own profession.

But With Respect to What They Can or Could Accomplish.—

Their yield is measurable in the discovery of previously unrecognized disease, an appreciable portion of which is still asymptomatic. Evidence exists that the early diagnosis and treatment of some diseases increase the likelihood that their treatment will be successful.

They allow us an opportunity to stimulate patients to obtain care or observation needed for known but neglected disease as well as for newly diagnosed disease.

They provide us with base line data which often prove useful later in making the correct diagnosis of an acute or chronic illness when this depends upon the recognition of *changes*.

While they do not *prevent* disease, of course, they do, as a result of its early detection, frequently offer the possibility of preventing some of the complications or disabilities of disease and occasionally offer the possibility of stimulating action that *will* prevent disease.

Thorough analysis of the observations made during great numbers of such examinations, for which purpose the keeping of good records which lend themselves to such study is an obvious necessity, would probably contribute greatly to the store of our knowledge concerning both health and disease.

Finally, although this quite defies actual measurement, one of their greatest yields—possibly the greatest—is their educational value. They offer an opportunity to teach a patient in a highly personalized fashion something about the maintenance and improvement of his health. They direct his attention, at least intermittently, to an asset of untold value that he may otherwise tend to neglect and ignore. They help him develop the degree of respect for his health and the awareness of it necessary to stimulate him to have complaints or problems referable to health investigated promptly.

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OL.
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959

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PNEUMOCONIOSIS

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INTRODUCTION

THE term "pneumoconiosis" was originally derived by Zenker[1] from Greek roots meaning a dust condition of the lung. It has since become customary to limit the term to conditions of the lung associated with dust deposition. This excludes more generalized systemic reactions, such as lead or zinc poisoning, and transient local effects, such as bronchial asthma, due to dusts which are inhaled but not deposited in the parenchyma of the lung. Some authorities would further limit the term to dusts which produce clinical illness or disability, but this is unacceptable to most specialists in this field. It is more reasonable to include all conditions associated with dust deposits irrespective of the degree of pathologic or functional alteration of lung structure.

That exposure to air-borne dust may cause disease is a very old observation. One of the first to record the association was Pliny in the first century. Similarly, scattered references to an undue mortality, particularly from lung disease, among workers in various dusty trades are found in the literature during the seventeenth and eighteenth centuries.[2] During the nineteenth century, the pathology, chiefly fibrosis and phthisis, among various workmen exposed to industrial dusts, were carefully described by Peacock and Greenhow.[3] They found the dust of free silica in the lungs and examined it under polarized light. In general, however, there was little concerted effort to study the clinical diseases associated with dust exposure or to investigate systematically the causative factors prior to 1900.

Early in the twentieth century, a number of clinical, pathologic, and epidemiologic studies were made in the South African gold fields and in the mines and potteries of Great Britain.[2] The studies were supplemented and later extended in the United States by the Bureau of Mines in the mining industry and by the Public Health Service in other dusty trades.[4] These observations laid the groundwork of our present understanding of the pneumoconioses. The increased use of roentgenographic techniques during this century facilitated our recognition and understanding of these diseases immeasurably.

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The development and application of environmental control measures to prevent the inhalation of dangerous quantities of dust soon followed. Beginning with the 1940's, these measures were generally adopted throughout what are now referred to as "the traditionally dusty trades." There has been no abatement of this effort, but an accelerating industrialization, ever-increasing mechanization, and the introduction of new materials and processes have concomitantly increased the sources, variety, and amount of dust exposure in industry.

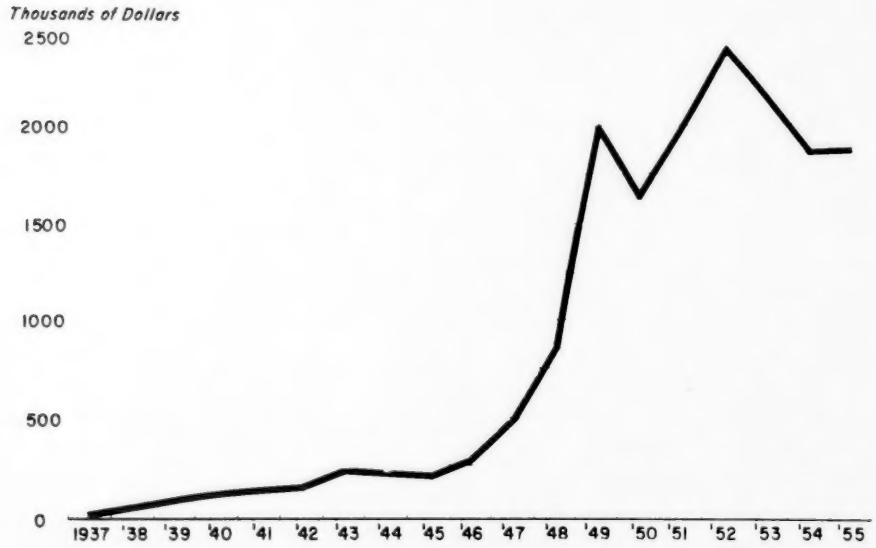

Fig. 1.—Amount of compensation paid in silicosis cases in New York State from 1937 to 1955.

PRESENT IMPORTANCE OF THE DISEASE

Despite the widespread use of engineering controls to reduce the dust inhaled by industrial workers, the problem of the pneumoconioses is far from eradicated today. That these control measures have been successful in certain previously highly hazardous industries is well established by studies such as one conducted in the Vermont granite industry which revealed no new cases since the installation of adequate controls.[5] On the other hand, a similar study of workers exposed to diatomaceous earth disclosed a surprising amount of pneumoconiosis produced by amorphous silica which had previously not been considered as pathogenic.[6]

Although there are no precise statistics on the actual incidence and prevalence of the pneumoconioses today, certain data indicate the size of the silicosis problem and the probable magnitude of the pneumoconioses as a group. One study of the prevalence of silicosis during the 5-year period from 1950 through 1954 in 22 states was based upon the number of cases awarded compensation. It is noteworthy that 10,362 cases were recorded, but even this figure is undoubtedly too low since a sizable number probably did not receive compensation be-

cause of technicalities in the law. The author[7] estimated that 13,000 cases might be a more accurate figure. While it must be recognized that many of these cases are no doubt attributable to exposures before the widespread initiation of control measures, it has also been established that a sizable number of them are due to more recent exposures.

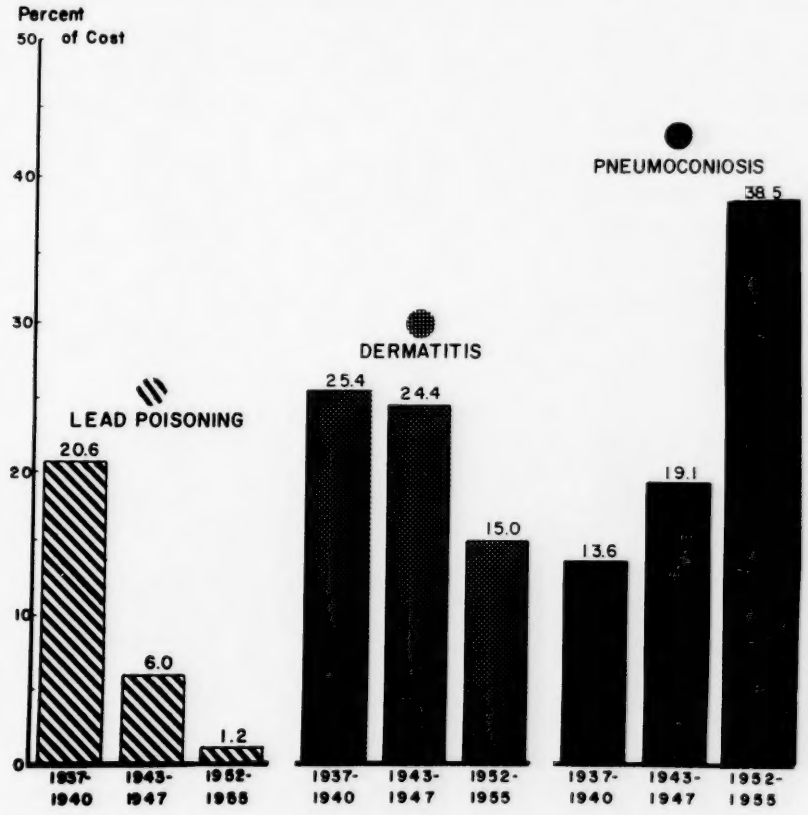

Fig. 2.—Compensation awarded in New York State from 1937 to 1955. Ratio of selected diseases to all occupational diseases. Source: New York State Workmen's Compensation Board.

Economic costs are another index to measure the importance of these diseases. Here again only partial data are available; nevertheless, these are revealing. The previously mentioned survey of silicosis disclosed that for 9,800 of the cases recorded between 1950 and 1955 in 18 states, the compensation costs were $43,700,000. An estimate of the total national compensation cost derived from this partial data is $10,000,000 per year.[8] The trend of compensation costs for silicosis over a 20-year period in New York State is seen in Fig. 1. Furthermore, other data made available by the New York State Workmen's Compensation Board demonstrate the increasing importance of the pneumoconioses compared to certain other industrial diseases, in terms of percentage of compensation costs (Fig. 2).

In addition to these direct costs, indirect costs, such as the loss of skilled workers to industry and the decrease in income to the ill worker, must also be considered. Of even greater significance are the human costs from disability and death of workers with pneumoconioses. This is well illustrated by the New York State Workmen's Compensation records for the period from 1953 through 1955 shown in Fig. 3.

These limited data are sufficient to demonstrate that pneumoconiosis remains one of the principal industrial diseases in terms of morbidity and economic costs. The incompleteness of the data, however, emphasizes the need for more complete statistical and epidemiologic information. Such information is vital for the evaluation of control and for a better understanding of the etiology and natural history of this group of diseases.

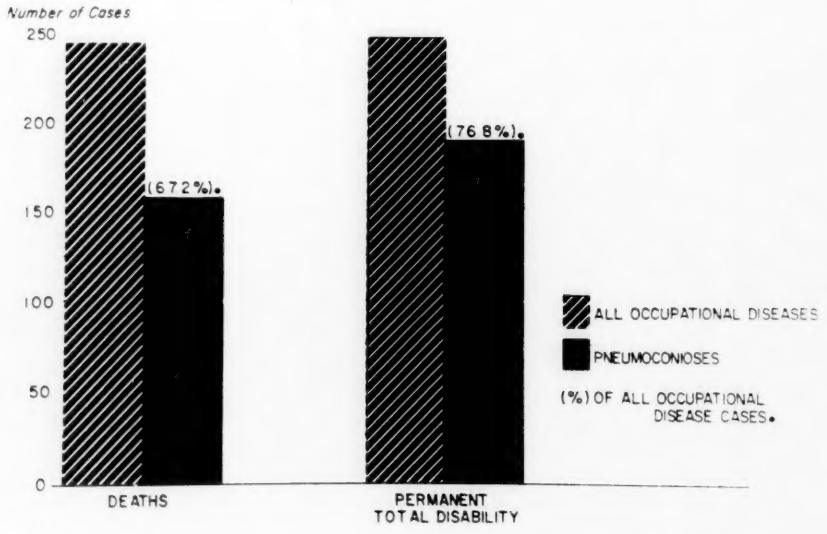

Fig. 3.—Death and permanent total cases closed in New York State from 1953 to 1955.

CLASSIFICATION

The pneumoconioses are best classified on the basis of the etiologic agent. It is also useful to group these agents according to the predominant reaction produced. Table I is an example of such a classification.

PREDISPOSING FACTORS IN THE DEVELOPMENT OF PNEUMOCONIOSIS

While each of the agents listed produces a fairly consistent clinical and pathologic picture, factors other than the nature of the dust per se are important in the development, severity, and rapidity of the changes observed. For example, particle size, the concentration of the dust in inspired air, duration of exposure, the presence of pre-existing lung disease, and individual susceptibility are all

TABLE I

I. Inert reactions
   - Graphite pneumoconiosis—carbon
   - Siderosis—iron
   - Baritosis—barium
   - Calcitosis—calcium
   - Stannosis—tin

II. Fibrogenic reaction
   - Silicosis—free silica (SiO_2)
   - Diatomaceous earth pneumoconiosis—amorphous silica
   - Anthracosilicosis—anthracite + free silica
   - Asbestosis—asbestos (hydrated magnesium silicate)
   - Coal miners' pneumoconiosis—coal dust
   - Berylliosis—beryllium metal or compound

III. Doubtful reactions
   - Talcosis—talc (hydrous magnesium silicate)
   - Mica pneumoconiosis—mica (magnesium aluminum silicate)

important in determining the course and end result in the individual patient. Moreover, as pointed out below, exposure to mixtures of various dusts may modify the pathology and further complicate the picture.

PATHOLOGY

Pulmonary Pathology of Dusts in General.—The pathology of the pneumoconioses represents, in every case, a balance between the defensive mechanism of the lung and the tissue reaction to the particular dust inhaled. Most of the dust inhaled never reaches the alveoli but is filtered out by ciliary action in the nasal passages or deposited on the bronchial mucosa, and is extruded by the normal cleansing action. In general, only the smaller particles gain access to the alveoli; the maximum size is about 5 micra for silica and about 100 micra for asbestos but is less definitely known for the other dusts. At one time it was believed that very small particles, below 0.1 micron, were harmless, but this idea has been challenged and there is some evidence that even submicroscopic particles may be harmful.

The particles reaching the alveoli are phagocytized by histiocytes. Some of these phagocytes migrate toward the bronchiolar mucosa where the ciliary action sweeps them out. More of them penetrate the respiratory membrane and move into the lymphatic spaces about the smaller blood vessels and bronchioles. The extent to which this defensive mechanism can be effective will depend upon the load presented for removal and on the concentration of the smaller particles in the air breathed. As the load increases more histiocytes become overladen with dust, and a certain number will disintegrate and again release dust within the parenchymal tissue.

Depending on the nature of the dust, one of several reactions may then occur. The dust particles deposited about the finer respiratory and vascular channels may: (1) remain inert, as in siderosis and baritosis; (2) set up low-grade local inflammation and fibrosis, as in coal-miners' pneumoconiosis; (3) initiate an acute inflammatory response which resolves without fibrosis, as in vanadium poisoning or acute berylliosis; (4) produce a local inflammation which progresses to diffuse parenchymal fibrosis, as in asbestosis; (5) initiate a lesser degree of local inflammation which stimulates further transport to the lymphatics and lymph nodes where slowly progressive fibrosis may occur, as in silicosis.

The dust load and the resultant fibrosis will further interfere with drainage and aggravate the anatomic changes. This helps to explain the importance of the duration as well as the intensity of exposure and the progressive nature of most of the fibrogenic dust diseases after the exposure ceases. No dust, however, exhibits any one of these five reactions to the exclusion of all others.[9,10]

Pulmonary Effects of Specific Dusts.—Each pneumoconiotic dust produces a fairly specific variation of this general picture. Since knowledge of these changes assists in the understanding of the clinical and roentgenologic manifestations of each specific pneumoconiosis, these effects will be presented first.

Silica: Silicosis, caused by the inhalation of crystalline silica, silicon dioxide, is by far the most common form of pulmonary dust disease. This disease is characterized pathologically by the presence of nodules which consist of concentric whorls of dense reticular and collagenous fibers (Fig. 4). Although the nodules appear to be distributed throughout the lung fields, careful study reveals that they follow closely the course of the pulmonary artery and its branches. As the disease progresses and the fibrosis becomes more extensive, the alveoli become distorted and many of the interalveolar septa disappear. Marked basal emphysema may be found, particularly in older individuals. In contrast, the apices may appear as mats of hard inelastic scar tissue as a result of condensation of the nodules. Tumorlike masses formed by coalescence of the nodules appear later in the disease and almost always indicate the presence of infection, particularly tuberculosis. Cavitation and caseation may follow.[9]

Although crystalline silica was once believed to be the only harmful siliceous agent, amorphous silica, particularly in diatomaceous earth exposure, is now recognized as another pneumoconiotic dust. In contrast to the effects mentioned, diatomaceous earth pneumoconiosis is characterized anatomically by diffuse fibrosis without discrete nodulation.[6]

Silicates: The most notable among the silicates is asbestos, a calcium magnesium trisilicate. Asbestosis is characterized anatomically by a generalized fibrosis associated with diffuse thickening of the alveolar walls. With progression, areas of dense fibrous condensation and emphysematous change appear. The findings are usually concentrated in the mid and lower lung fields with the apices relatively spared. Bronchiectases are present within the substance of the fibroid areas. In contrast to silicosis, this fibrosis more often is non-nodular in type. There is not infrequently a marked pleural reaction with pleural and pericardial plaque formation and emphysematous changes.[9]

Fig. 4.—Photomicrograph of a section of lung tissue in a patient with silicosis. Nodules of varying size consisting of concentric whorls of dense retricular and collagenous fibers are seen. There is coalescense of some of these nodules. The alveoli are distorted and emphysema is present.

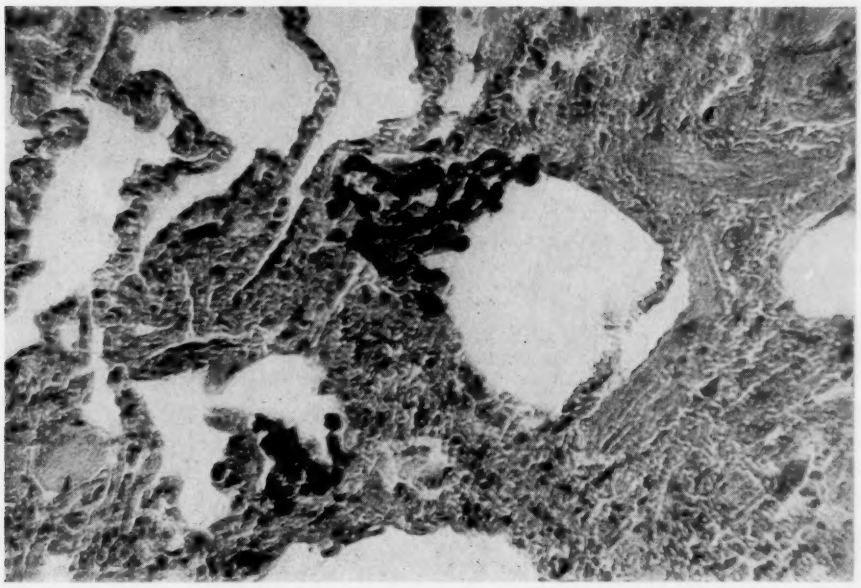

Fig. 5.—Photomicrograph of a section of lung in a patient with pulmonary talcosis. Extensive diffuse fibrosis with thickening of the alveolar walls is observed. Peculiar to asbestosis and the asbestine variety of talc is the occurrence of asbestos bodies. The latter are dumbbell in shape with rounded bulbous ends and are recognized by their beaded appearance.

OL.
9
959

Talc is another silicate. Of pathologic significance is the asbestine variety known as tremolite talc which produces an anatomic picture similar to that of asbestosis.[11,12]

Peculiar to asbestosis and the asbestine variety of talc are the presence of "asbestos bodies." When microscopic sections of lung tissue are stained with Prussian blue, these bodies can be seen to consist of fibers of the mineral surrounded by protein deposits. The fibers are dumbbell in shape with rounded bulbous ends and are recognized by their beaded appearance (Fig. 5).

Coal: The pulmonary disease found in coal miners has long been attributed to the presence of free silica in the shale through which miners have to dig to get at the coal. Recent studies in England clearly indicate that exposure to high concentrations of coal dust with only negligible amounts of free silica produces a form of pneumoconiosis differing from anthracosilicosis and silicosis in general. Initially, the essential lesion as described by Heppleston[13] is characterized by deposits of dust-laden macrophages enmeshed in a reticulum framework forming cuffs around the respiratory bronchioles. They are often surrounded by focal emphysema. Collagen fibers are usually scanty in the uncomplicated case. With infection, particularly tuberculosis, the collagen fibers increase and may undergo hyaline changes. At times, central ischemic necrosis is found. With further progression there follows a massive fibrosis consisting of dense collagen tissue containing a large amount of coal dust (Fig. 11). An increased incidence of rheumatoid arthritis has been found to be associated with this form of progressive massive fibrosis.[14]

Beryllium: Of the metallic dusts, beryllium more than others properly belongs in a discussion of the pneumoconioses. In the chronic form of exposure noncaseating discrete granulomas are found situated in the interstitial tissues of the lung associated with diffuse thickening of the alveolar walls. These granulomas further stimulate the production of scar tissue and more generalized pulmonary fibrosis appears later in the disease. Of equal importance is the chronic imflammatory reaction observed in various portions of the lung parenchyma.[15]

Iron: Although the roentgenologic manifestations of the pneumoconioses due to inert dusts may simulate to a great extent those of uncomplicated silicosis, the pathologic findings are considerably different. For example, in siderosis, phagocytized iron particles are seen deposited in nodular fashion along the lymphatics in sections of lung tissue. However, there is no tendency toward confluent nodulation or fibrosis.[16] Likewise, siderosis does not predispose to tuberculosis.

DIAGNOSIS

A diagnosis of pneumoconiosis requires that the following three conditions be met: (1) an adequate occupational exposure to the dust in question, (2) a roentogenographic picture that is compatible, and (3) a fairly characteristic clinical picture consistent with the dust exposure.

VOL 9 195

Occupational Exposure.—The absolute minimum required to meet the first criterion is that the patient worked in an atmosphere containing one of the dusts known to produce lung disease. If such a history cannot be elicited, the diagnosis is in general untenable regardless of other findings. However, it is possible for people living near a dusty plant to develop a pneumoconiosis. The development of berylliosis in some people living within a three-fourth mile radius of a beryllium processing plant illustrates this.[17] Whenever possible, the duration of the exposure and the concentration and particle size of the dust should be ascertained. The longer the exposure, the greater the concentration, and the finer the particles, the more likely is the diagnosis. This is particularly important where roentgenographic or clinical findings are doubtful. The literature, however, gives undue stress to these quantitative factors. There are other factors such as individual susceptibility and the presence of pre-existing lung disease which must be seriously considered in establishing a diagnosis of pneumoconiosis, even though the degree and duration of exposure do not appear adequate.

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959

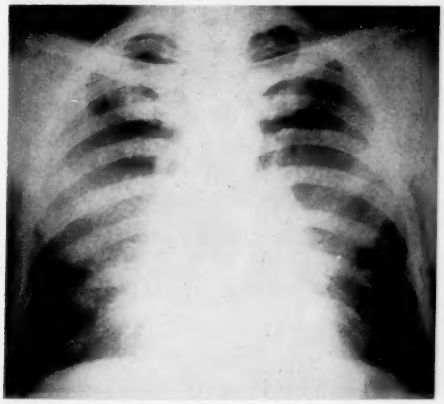

Fig. 6.—Posteroanterior view of chest showing small discrete uniform nodules are scattered bilaterally throughout the lung parenchyma. Note that these nodules are well defined and occur predominantly in the perihilar and mid-lung regions (silicosis).

Roentgenographic Picture.—The roentgenographic picture, although not pathognomonic for pneumoconiosis, should be compatible with the changes produced by the particular dust to which the patient has been exposed. While there is considerable overlapping and individual variation, the picture for each of the major dust offenders has certain distinguishing features which are of considerable diagnostic help.

The x-ray findings in silicosis vary with the stages of the disease. Initially, the roentgenograph may show only an increase in linear markings of the lungs due to the accumulation of the dust within the lymphatics. At this stage, the x-ray cannot be considered diagnostic of silicosis. In simple uncomplicated silicosis, the x-ray picture is predominantly one of small discrete uniform nodules scattered bilaterally throughout the lung parenchyma. These nodules have well-defined borders and usually occur in the perihilar and mid-lung regions (Fig. 6). As the disease progresses, the nodules become larger and increase in

number and their borders do not remain well defined. Although local emphysema may be present throughout the lung, a more diffuse basal emphysema is common in the later stages. Conglomerate shadows appearing as large masses, more often located in the upper lung fields, are usually seen when silicosis is complicated by infection.

In contrast to silicosis, asbestosis and talcosis initially present a fine haziness in the lower lung fields creating a "ground glass" appearance. Subsequently, there is increasing evidence of more extensive and coarser fibrosis with variable degrees of pleural thickening (Figs. 7 and 8). A striking finding is the presence of opaque densities varying from single linear strands in the region of the diaphragm to massive deposits, bizarre in shape, over a large part of the lung fields and occasionally on the pericardium. These are referred to as "plaques" (Fig. 8).

In the chronic form of berylliosis the earliest change is a diffuse, finely granular appearance throughout both lungs. Both apices and bases are involved. Paratracheal masses and enlarged hilar shadows are seen in many cases. With progression of disease, fine nodulation appears on granular background. Confluence of nodules is less in evidence than in silicosis. Emphysema may follow and is usually seen at apices and bases (Fig. 9).

Uncomplicated coal miners' pneumoconiosis may have only minimal roentgenologic findings even when clinical disability exists. Areas of the disease are often masked by sufficient layers of normal lung tissue. Initially the x-ray of the chest is one of reticulation rather than nodularity. However, when the disease progresses, miliary or nodular densities fairly well defined in outline are seen throughout the medial two-thirds of the lungs. They are usually arranged in clumps. Local areas of emphysema are frequently present.

Pneumoconiosis due to the inert dusts, such as siderosis, present initially an increase in the normal lung markings as the dust is deposited peribronchially and perivascularly; later the reticulation becomes more diffuse. Fine nodulations uniformly distributed in both lung fields may be seen (Fig. 10).

When complications supervene, the roentgenologic features are distinctly modified. When infection, chiefly tuberculosis, complicates the pneumoconiosis, larger x-ray shadows are usually seen and cavitation may be apparent. Silicosis is especially apt to become complicated by tuberculosis. In contrast, workers with diatomaceous earth pneumoconiosis apparently show no greater incidence of tuberculosis than do workers without exposure to dust. If the tuberculosis is chiefly exudative and caseating, pulmonary infiltrations, cavitation, and bronchogenic spreads may occur; this has been called silicosis with tuberculosis. If the tuberculosis is chiefly productive, there may be only slow enlargement of the conglomerate masses with less other evidence of active infection; this has been called tuberculosilicosis to distinguish it from the more malignant form. In the complicated pneumoconiosis of coal miners, the localized opacities progress to the formation of large massive shadows which are fairly distinct radiologically.

When the pneumoconiosis is of long-standing, cor pulmonale may complicate the clinical picture of the fibrosing pneumoconiosis. In the cases of asbestosis, the superimposition of bronchogenic carcinoma is not infrequent.[18] The x-ray

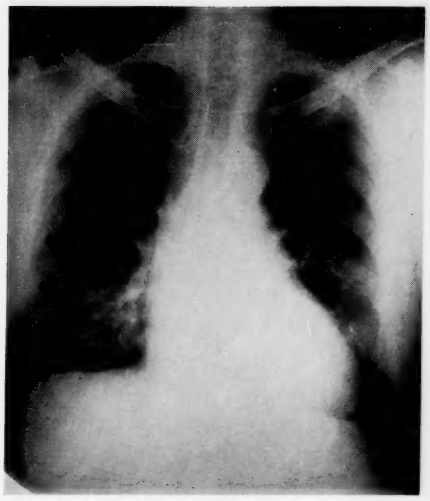

Fig. 7.

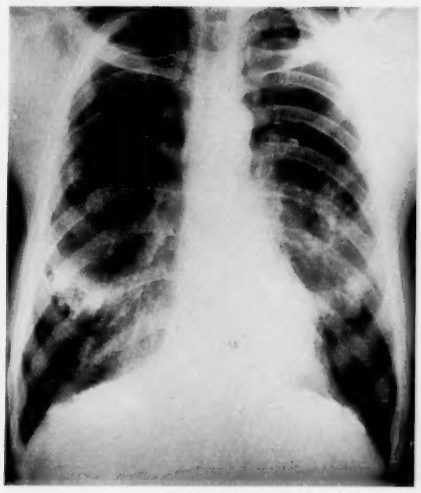

Fig. 8.

Fig. 7.—Posteroanterior section of chest of patient with known asbestosis showing the presence of increased reticulation predominantly at bases.

Fig. 8.—Posteroanterior view of chest showing the pulmonary infiltration in the mid-lung and basilar area. Note the diaphragmatic and pleural calcifications characteristic of talc pneumoconiosis.

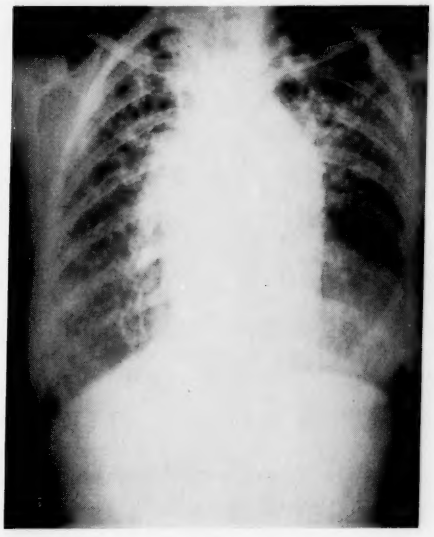

Fig. 9.

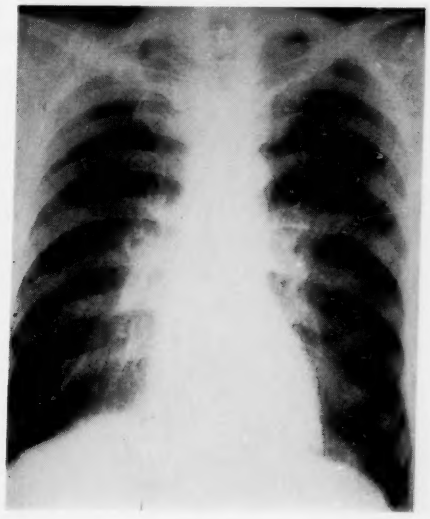

Fig. 10.

Fig. 9.—Posteroanterior view of chest in a patient with known berylliosis showing increased hilar shadows and coarse nodulations distributed throughout both lung fields.

Fig. 10.—Posteroanterior view of chest showing increased reticulation and fine nodules uniformly distributed in both lung fields (siderosis).

may not be sufficiently characteristic to be pathognomonic of a dust disease. In this respect such conditions as Boeck's sarcoid, lymphangytic carcinomatosis of the lungs, calcium siderosis associated with mitral stenosis, and miliary tuberculosis cannot be ruled out on the basis of a roentgenogram. The physician inexperienced in dust diseases will find the interpretation of such x-rays more difficult. Even the expert will be more confident if serial films are available and will frequently supplement them with special views and fluoroscopy.[19]

Clinical Picture.—The first two criteria are adequate for the diagnosis of the group of benign pneumoconioses which do not produce clinical disease, i.e., those associated with an inert reaction such as siderosis. In this regard it is well to remember that once such a diagnosis is established, other explanations for any existing symptomatology must be sought.

On the other hand, the symptomatic pneumoconioses are usually manifested by a slow, steady, insidious progression of dyspnea, cough, and sputum and are frequently associated with mild-to-moderate weight loss and easy fatigability. Once such complications as infection, right heart failure, or bronchogenic carcinoma supervene, the clinical picture is modified accordingly.

VOL. 9 1959

It is important to realize that roentgenographic evidence of the pneumoconiosis may appear long before the symptomatology becomes troublesome to the patient. In fact, this may not occur until the complications arise.

For the most part, all of the uncomplicated pneumoconioses are characterized by a paucity of physical findings and this is particularly true in the early stages of the disease. Even in the presence of established roentgenographic changes, percussion and auscultation of the chest frequently suggest no abnormality. On the other hand, a whole range of abnormal physical signs may be noted as the disease progresses. A varying degree of râles, altered breath sounds, and areas of dullness and resonance can be found. As the lungs become increasingly emphysematous, cyanosis of the lips and nails, neck vein engorgement, limited chest wall motion, and hyperresonance on auscultation can be elicited. When the disease is of sufficient duration, clubbing of the fingers and toes often appears.

DIFFERENTIAL DIAGNOSIS

Differential diagnosis is not difficult in the majority of cases. Although many diseases, including such common conditions as viral and bacterial pneumonia and pulmonary edema, may imitate the dust disease, there are other characteristics which readily identify them in most instances. Chronic disorders such as sarcoidosis, histoplasmosis, coccidiomycosis, Hamman-Rich syndrome, and the diffuse mottling secondary to mitral stenosis may present more difficulty. Certain unusual and bizarre cases of pneumoconiosis may imitate carcinoma of the lung.[20] Perhaps the most difficult cases are those with respiratory disability, diffuse pulmonary fibrosis and emphysema by x-ray, and a history of exposure to a dust of doubtful duration, concentration, composition, or nature. The final differentiation may be possible only by a lung or node biopsy or an autopsy. Occasionally pulmonary function tests may be helpful, particularly

Fig. 11.—Gough-Wentworth section showing coal miners' pneumoconiosis. Section shows numerous coal nodules with focal emphysema. There are extensive areas of fibrosis. There is coalescence of some of the fibrotic areas. (Courtesy of Leonard J. Goldwater, M.D.)

in distinguishing those disorders which primarily effect the mechanical component of ventilation from those which produce a physicochemical disturbance. For example, silicosis and diatomaceous earth pneumoconiosis primarily alter the breathing mechanics, whereas sarcoidosis and Hamman-Rich syndrome produce a disturbance in diffusion across the pulmonary alveolar capillary bed. Similarly, asbestosis and berylliosis, because of a similar functional derangement, can be differentiated from those disorders which affect primarily the mechanics of breathing. However, in the later stages of these diseases changes in both respiratory components are seen and the differentiation becomes less evident.[21]

As has already been mentioned, there are pitfalls and difficulties associated with each of the three criteria discussed. A thorough knowledge of industrial materials and processes is required to evaluate the occupational exposure. Many errors of both omission and commission are made through lack of knowledge as to where the dangerous dusts are used and which processes produce them in significant concentrations. The workman himself often does not know the exact nature of the materials he is exposed to and can rarely give a meaningful estimate of the amount of dust generated. It cannot be overemphasized that a thorough familiarity with industrial materials and processes gives more reliable knowledge of the probable degree of exposure than do brief air samples taken many years after the dangerous exposure has occurred.

It is recognized that errors in x-ray interpretation have not been infrequent in the past because of undue emphasis on nodular fibrosis as the sole criterion of silicosis. Appreciation of the importance of fine reticulation, reticulation with micronodulation, ground-glass haziness, and emphysema is only fairly recent and requires further stress.

Despite repeated emphasis in the literature, it is still not sufficiently appreciated that the clinical and x-ray manifestations in the individual case are frequently not closely correlated. There may be extensive roentgenographic changes with only minimal or no symptoms and no disability. Approximately one-fourth of the men in a group of rock drillers studied in New York whose chest x-rays suggested advanced silicosis had no complaints whatever and the same was true among a group of granite cutters.[22] What is even less well appreciated is that there may be severe disability in the presence of minimal x-ray changes. These individuals will usually show a more diffuse fibrosis and considerable emphysema pathologically which occasionally is difficult to visualize by x-ray films.

TREATMENT

The only effective treatment is prevention. Despite a great deal of work on aluminum therapy for the prevention and treatment of silicosis, its efficacy is still doubtful.

The most effective preventive measures have been environmental. The purpose of the various engineering procedures employed in industry is to prevent access of dust to the inspired air. This is accomplished through such means as wetting the dust at its source, enclosure of the dusty process, and exhaust

VOL. 9 195

ventilation at the point of operation. By far the most desirable procedure, wherever feasible, is the substitution of less dangerous dusts. This has been achieved in some instances in foundries where steel shots have been substituted for sand in the sandblasting of molds. Masks, in general, are a poor substitute for more effective control but may be the only protection practicable in a few special situations. Periodic industrial hygiene surveys which include testing of the ventilation system and analysis of the air at the breathing zone of the operator and in the room are important engineering control procedures.

Medical controls also have a vital preventive role. Pre-employment examination to exclude individuals with pneumoconiosis acquired previously and those likely to be predisposed to its development because of pre-existing lung disease is of value as a control technique. Periodic follow-up examinations to detect the earliest evidence of disease so as to remove the individual from further exposure is equally important.

There are other areas which have not been sufficiently exploited by industrial physicians charged with this responsibility. One is the use and standardization of tests of respiratory reserve. There is some evidence that a significant loss of reserve, detectable only by comparison with the individual's previous performance, may precede roentgenographic changes in some individuals.[23] Another area is the epidemiologic study of the pneumoconioses, particularly the mixed and newer dusts. This type of data would greatly assist in the evaluation of present control measures and in further elucidating the etiology and natural history of the dust diseases.

PROBLEM AREAS IN PNEUMOCONIOSIS OF CURRENT INTEREST

There are a number of current problems in pneumoconiosis which require more intensive study before clear-cut and satisfactory answers are found. The following material illustrates some of these areas.

Pathogenicity of Doubtful and Mixed Dusts.—There is a need to clarify the pathogenicity of doubtful, mixed, and previously unsuspected dusts. Epidemiologic studies of groups of exposed workers and physical-chemical studies of the air-borne dust will help elucidate this problem. Although animal work is helpful in studying the pathogenesis of these dusts, it cannot give a definitive evaluation of the pathogenesis of the dust for man.

Estimation of Disability.—A problem of great medicolegal and socioeconomic significance is the estimation of disability. The doubtful pathogenicity of various exposures and the discrepancy between x-ray and clinical manifestations already pointed out complicate this problem greatly. The variety of physiologic tests developed are useful when correlated with the other evidence but they should not be relied on too heavily or exclusively. The basis for evaluation should include a careful long-term follow-up on individual cases. There is a need for the development of better and more widely accepted indices indicative of total disability as well as reliable indices which express degrees of disability. The latter is particularly needed and calls for more intensive research.

Prepathogenetic Tests of Pulmonary Dysfunction.—This is another important area which requires time, effort, and talent. In general, the information to date is meager and yet the need is paramount if real progress in the control of pneumoconiosis is to be made. To enhance control one must detect an effect of the dust prior to the occurrence of an abnormal chest x-ray or overt clinical symptoms.

Improvement of Workmen's Compensation Laws.—There is a lack of consistency of these laws in the various states. In 22 states the benefits for pneumoconioses are subject to limitations which do not apply to traumatic injury. In 20 states total disability is defined in four different ways and is left undefined in twenty-five.[24] Probably the most inequitable provision in view of the medical facts is the time limitation which excludes claims not made within a varying stated interval after exposure. There is, therefore, a great need for consistency and a clearer recognition of the medical facts.

VOL 9 195

SUMMARY AND CONCLUSIONS

A discussion of the pneumoconioses in the light of historical background, incidence, classification, pathology, diagnosis, and treatment is presented.

The real importance of silicosis in terms of incidence, morbidity, and costs and the magnitude of the pneumoconioses as a group are demonstrated.

A classification based upon etiology and the predominant pulmonary reaction is included.

The pulmonary pathology of the pneumoconiotic dusts in general and the more specific pulmonary effects of certain dusts are described. The pulmonary pathology associated with dusts other than crystalline silica and asbestos, such as coal (coal miners' pneumoconiosis), tremolite talc (pulmonary talcosis), and amorphous silica (diatomaceous earth pneumoconiosis) is emphasized in the light of the changing concepts in pathogenicity of these dusts.

The minimal criteria essential for establishing a diagnosis of pneumoconiosis are an adequate history of occupational dust exposure, a roentgenographic picture compatible with industrial dust disease, and a fairly characteristic clinical picture consistent with dust exposure. The pitfalls and difficulties associated with each of these criteria are mentioned.

It is pointed out that the only effective treatment is prevention and this requires essentially engineering procedures. The latter include dust suppression techniques and substitution of less dangerous dusts. Medical procedures, such as pre-employment examinations to exclude workers with already-existing lung disease and periodic follow-up examinations to detect early evidence of disease, are also important in prevention and control.

A number of problem areas of current interest are mentioned. Particular emphasis is given to the needs for (1) clarifying the pathogenicity of doubtful and mixed dusts, (2) estimating disability, (3) prepathogenetic tests of pulmonary dysfunction, and (4) improving the consistency and better recognition of the medical facts in Workmen's Compensation Laws.

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959

CHRONIC EFFECTS OF IONIZING RADIATION: INDUSTRIAL EXPERIENCE

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NEW YORK, N. Y.

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VOL
9
195

INTRODUCTION

HUMAN beings have always been exposed to ionizing radiation from natural sources. It now appears probable that somewhat less than half of the "spontaneous" mutations in man are caused by radiations from these sources. The pulmonary carcinomas among Central European pitchblende miners were also, at least in part, due to the natural radioactivity of the rock formations and ores. However, it was only following the discoveries of Roentgen and Becquerel, at the turn of the century, that obvious harmful effects became manifest. One hundred and seventy cases of injury among the early investigators within the first 5 years was concrete evidence of the harmfulness of ionizing radiation.

The subsequent rapid development and application of x-rays and radium to diagnostic and therapeutic medicine also produced injuries among the first physicians using these modalities. In this era of unprotected investigation, injuries to radiologists were more frequent than to the patients, and, by 1922, 100 radiologists had died from the effects of radiation. In 1921, the first national scientific organization to recommend and promote appropriate protective measures was established. Two principles of control, shielding and distance, were apparent from the physical characteristic of radiation, and the third principle, limiting exposure, became evident when it was recognized that to some extent radiation injury is cumulative. Internal deposition of radium in the processing of radium for medical purposes and in its use in painting luminous dials resulted in scores of deaths from malignancy and blood dyscrasia. The resultant emphasis on the danger from the absorption of radioactive material led to the successful application of the fundamental industrial hygiene principles (of substitution, isolation, and ventilation) used for other air-borne toxins.

Despite the relative frequency of injury in these early days, exposure was limited to specialized groups of physicists and physicians and a small group of nontechnical workers engaged in the processing and use of radium. Although the severe and fatal intoxications in the radium dial painters caused a minor sensation at the time, public knowledge and concern were limited until the discovery of nuclear fission. The development and application of nuclear physics

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to military and industrial uses has greatly increased the number of healthy people exposed. Concommitant advances in radiobiology have demonstrated that the general public, as well as workers in the field, may be adversely affected by ionizing radiation, even apart from the catastrophic effects of nuclear warfare. As a result, widespread concern, verging on hysteria in some cases, has arisen about the effects of radiation. For obvious reasons, interest among the general public as well as workers in the field has especially focused on the long-term insidious effects.

SOURCES

Table I lists briefly the more important sources of ionizing radiation. Space does not permit detailed discussion of the various components of each source and their relative magnitudes, but certain generalizations are possible. Fortunately, those sources to which the greatest number of people are exposed, such as natural or background radiation, luminous watch dials, and fall-out, are presently of the least magnitude. Even here there are wide variations between various geographic areas and population groups, so that average values require qualification.

TABLE I. SOURCES OF IONIZING RADIATION

Natural Sources	
Cosmic radiations	
Terrestrial radiations (ground, air, and building materials)	
Normal body constituents (portion of element, e.g., K, occurs as radioactive isotope, K_{40})	
Occupational sources	
Industrial workers	
Medical personnel	
Atomic energy workers	
Research workers	
Medical uses	
Diagnostic x-rays	
Radiotherapy with x-rays and external radioactive materials	
Diagnosis and therapy with isotopes internally	
Other man-made sources	
Luminous dials	
X-rays from high voltage thermionic equipment	
Shoe-fitting fluoroscopes	
Environmental contamination	
Radioactive fall-out	initially external and subsequently internal
Radioactive waste	
Catastrophic sources	
Accidents (industrial, medical research, atomic energy weapon testing)	
Nuclear warfare	

Occupational exposures are of somewhat greater magnitude but involve smaller groups of people. They include exposures of radiologists and technicians in the medical use of radiation and of workmen in its industrial use; the present extent of the latter use is roughly indicated by data from one highly indus-

TABLE II. TYPES OF RADIATION-PRODUCING EQUIPMENT AND RADIOACTIVE MATERIALS*

	NUMBER OF SOURCES	QUANTITY IN CURIES
Radiation-producing equipment		
Industrial x-rays	356	
Radioactive static eliminators	1,607	
Radioactive gauges	220	
High-voltage thermionic	785	
Particle accelerators	15	
Neutron sources	9	
Nuclear reactors	7	
Radioactive materials		
Small sealed sources		13.718
Large sealed sources		34,100.930
Unsealed isotopes		6,059.181
Radium and daughter products		3.169
Unsealed uranium and thorium		5.760
Irradiated activated materials		0.570
Fission products and other waste		59.051

*Adapted from Kleinfeld, Morris: New York's Experience in Administering Code on Radiation Protection, A.M.A. Arch. Indust. Health **17**:87, 1958

TABLE III. INDUSTRIAL SOURCES OF IONIZING RADIATION*

INDUSTRY	SOURCES OF RADIATION
Mining	3
Manufacturing	
Stone, clay, and glass	19
Primary metals	32
Fabricated metals	50
Machinery, nonelectrical	37
Machinery, electrical	69
Transportation equipment	39
Instruments	76
Food and kindred products	4
Textile mills	22
Apparel	4
Paper and allied products	21
Printing and publishing	34
Chemical and allied products	93
Petroleum and coal products	11
Rubber products	7
Leather products	2
Miscellaneous products	15
Public utilities	23
Wholesale and retail trade	5
Service industries	33
Research	62
Not otherwise classified	3

*Adapted from Kleinfeld, Morris: New York's Experience in Administering Code on Radiation Protection, A.M.A. Arch. Indust. Health **17**:87, 1958.

trialized state. Table II indicates the number of radiation-producing sources and amounts of radioactive material for various industrial applications in New York State. It has been estimated that approximately 3,500 workers are exposed to the sources listed. The potential for industrial use is better indicated by Table III which shows the distribution of the various categories in Table II among the various industries in this state. The diligent application of the control principles already mentioned has not only minimized the (in some cases), potentially large, exposures in industry, but has also reduced the individual variation in exposure from these sources to a common low average.

Medical exposures of patients, which are relatively large in some cases and involve large numbers of people, constitute the principal real hazard at present. However, even within this group, the larger numbers of patients are exposed to lesser quantities of radiation, e.g., radiographic chest surveys. The larger doses are now used for relatively few people and usually for medical conditions, like malignancy, which far outweigh the possible hazard to the individual and tend to preclude the transmission of a genetic defect. Nevertheless, despite the long-standing awareness and unremitting efforts of competent radiologists, the problem of exposure from this source, particularly gonadal exposure, requires further attention. Additional reductions in the quantity, area, and frequency of exposure are possible.

The potential magnitude of exposure in the event of a catastrophe undoubtedly underlies the anxiety which is so often expressed as unwarranted hysteria over nonexistent dangers and undue concern over relatively minor hazards. While the possibility of accidental exposure is a very real one which will be discussed later, it appears unlikely, at present, that large numbers of people could be involved. While it is not possible to overemphasize the danger of atomic warfare, the long-term effects at Hiroshima and Nagasaki have been less than had at first been expected.

EFFECT

Knowledge of the effects of ionizing radiation is derived from observations in many areas. Animal experimentation has contributed chiefly to understanding the mechanisms and dose relationships. Human clinical effects have been studied in the professional and technical workers injured, in patients undergoing radiotherapy, in survivors at Hiroshima and Nagasaki, in the relatively small groups exposed during atomic bomb testing, and in the few industrial workers injured. The studies of radiologists and radium dial painters occupationally exposed have made an especially valuable contribution to clinical knowledge.

Epidemiologic studies on the first four groups mentioned have helped to delineate the long-term delayed effects suspected from animal work. It has also buttressed the dose relationships predicted. The resulting vast amount of information available prohibits even a brief comprehensive review here. Only the most important principles and the areas of greatest interest in terms of chronic industrial disease can be touched upon.

The deleterious effect of ionizing radiation is exerted at a cellular level by the release of energy incidental to the ionization which occurs. Thus, the cell

which "absorbs" the radiation is damaged; radiation which penetrates a cell without releasing energy, i.e., without "absorption," is harmless. The energy released may have two effects (not mutually exclusive): (1) it may alter a particular specific essential biochemical constituent deleteriously, or (2) it may decompose water or common organic molecules into highly reactive radicals which interfere with normal cellular metabolism. The deleterious effect may be manifested at a cellular level as a retardation of cell division, mutation of cell structure or function which is then passed on to subsequent generations of cells, or as cell death. Each of the several kinds of radiation (alpha, beta, gamma, etc.) acts through identical mechanisms to produce identical effects at this level. The complexity of the relationship between individual cell damage and the final effect on tissues, organs, individuals, and populations is familiar to all biologists and physicians. Such factors as the degree of differentiation of the affected cell, its structural or functional uniqueness in the tissue, the essentiality of the organ or system it helps compose, its rate of division or replacement, and secondary damage from injury to adjacent cells or distant organs will all be important in determining the final effect. Similarly, the age, current physiologic status, and genetic background of the individual will be important. In addition to these "host" factors, certain "agent" factors are of importance because they determine the particular kind and number of cells which will be damaged in a given situation. Among these "agent" factors are the physical characteristics of a particular radiation, such as its penetration, energy transfer, and secondary ionizing capacity. Equally important in determining the accessibility of the radiation to particular cells is the location of the source outside or inside the body. This explains the distinction made in Table I between "external" and "internal" sources. Only penetrating radiations like gamma and x-rays produce other than superficial effects from a source outside the body. Radioactive material, on the other hand, ingested or inhaled and retained in the body will continue to emit the forms of radiation which are characteristic for it. Another distinction between external and internal sources is that exposure to the former is usually intermittent and the area irradiated (whole body, eye, hands, etc.) is fairly definitely determinable, whereas exposure to the latter will depend upon the metabolic turnover (excretion, degradation, storage, etc.) and the particular site of localization of the particular element (radium, cesium, potassium, iodine, etc.).

In reviewing the various effects actually observed, it is important to appreciate that none of them is characteristic of ionizing radiation; identical injuries can be produced by other agents or can occur without identifiable cause. Acute exposures to large doses of radiation (limited external, whole body, or, rarely, large internal) produce chiefly skin, gastrointestinal, and hematologic lesions which may lead to collapse and death with sufficiently large doses. They are readily identifiable by the history of recent exposure, a short lag period between exposure and clinical signs, and the time course of subsequent developments. Severe forms were seen in the Japanese survivors and mild forms are seen in the course of radiotherapy. These acute manifestations are not the chief concern here.

VOL
9
195

Chronic effects are conveniently separated into somatic and genetic. A wide variety of somatic effects has been observed in man and animals. Most of them have been produced by doses in the order of 100 r. or more delivered to one portion of the body, but all of them can be produced by a slightly larger total dose distributed over a longer time. There is always a latent period of a few days even with a single large dose, and it may extend to several years depending upon the total dose, its time distribution, and the particular effect observed. The lesions seen will represent in most cases both the original damage and the efforts at repair. This is particularly true of the skin and gastrointestinal tract. The more important human lesions seen are listed in Table IV. All of them are dose dependent within the usual biologic limits and for all, except possibly the leukemias, there is a reasonably definite threshold dose below which no detectable effect is seen.

TABLE IV. EFFECTS OF IONIZING RADIATION ON HUMANS

Blood-forming organs	Gastrointestinal system
Lymphopenia and altered morphology	Loss of motility
Leukopenia	Decreased secretion
Aplastic anemia	Denudation of mucosa
Leukemias	Ulceration
Skin	Infection with bacteria
Transient erythema	Scarring and stenosis
Edema (vesicles and bullae)	Vascular system
Desquamation	Often factor in other lesions
Pigmentary changes	Altered permeability
Transient hair loss	Dilatation
Permanent alopecia	Necrosis with rupture
Nail damage (fissuring and loss)	Obliteration
Necrosis	Eyes
Ulceration	Conjunctivitis
Scarring	Keratitis
Telangiectasis	Cataracts
Carcinoma	Liver
Sarcoma of cutis	Carcinoma
Bone	Thyroid
Inhabition of growth	Suppression of function
Necrosis	Carcinoma
Sarcoma	Gonads
	Sterilization
	Embryonic
	Malformations

Carcinoma of the skin and lung, and sarcoma of the cutis, bone, and adjacent structures develop almost exclusively in the areas showing evidence of previous damage. The latent period for these malignant tumors is often 10 to 20 years and may be even longer. Leukemias, on the other hand, may develop without evidence of preceding damage. Their latent period is somewhat shorter (5 to 10 years) and the incidence of each type of leukemia tends to approximate that found in the unexposed population. The evidence for the existence of a threshold dose for leukemia is conflicting and has been variously interpreted.

In addition to these known chronic somatic effects, certain less specific effects have been postulated, chiefly from animal work. This work indicates that, even in the absence of detectable specific effects, exposure to radiation may increase susceptibility to infection, interfere with reparative processes generally, and shorten life span. While there is suggestive data that the last of these may also be true for man, it is not yet possible to reach a definite conclusion.

Animal evidence also establishes beyond reasonable doubt that exposure to ionizing radiation increases the rate of mutation in a linear fashion. There is no threshold dose; increasing the dose to a population increases the number of mutations, but there is no "safe" level below which mutations will not be produced. There is, of course, no reason to believe the same relationship does not hold for man although it is much less susceptible to proof for obvious reasons. This is the chief reason for intelligent concern about the exposure of the whole population and is the basis for the present discussions of the maximum permissible dose for radiation workers and the population at large. Table V indicates the estimated per capita gonadal exposure from the various sources at the present time. The usual reproductive period of 30 years is chosen and figures are given for fall-out if weapons testing should cease at the end of 1958 and if it should continue at the present rate until equilibrium is reached in about a century.

VOL. 9 195

TABLE V. GONADAL DOSE OF IONIZING RADIATION*

SOURCE	MAXIMUM GENETICALLY SIGNIFICANT DOSE FOR ANY 30-YEAR PERIOD (IN ROENTGENS)
Natural	3
Medical	
Diagnostic	0.60–4.50
Therapeutic	0.03–0.90
Internal	Less than 0.03
Total all medical	0.50–5.00
Occupational	Less than 0.06
Environmental	
If weapons test cease at end of 1958	0.01
If weapons test continue until equilibrium is reached (2058)	0.06

*Adapted from: Report of the United Nations Scientific Committee on the Effects of Atomic Radiation, General Assembly, Official Records, Thirteenth Session, Supplement No. 17 (A/3838) New York, 1958, p. 37.

INDUSTRIAL EXPERIENCE

Review of experience with ionizing radiation in research work, the Manhattan Project, the Atomic Energy Commission, and private industry demonstrates that important lessons have been learned. Some of these have wider application in a world of rapid technologic advance where additional potentially harmful modalities are constantly being introduced and ever more subtle effects

are being recognized and combatted. As has been pointed out, following the initial injuries to the research workers, controls were rapidly developed and applied. By the time radiation found industrial use, chiefly for the radiography of metals and as static eliminators, the hazards were well known and controls were incorporated as an essential part of the operation. As a result, overexposure or injury was limited almost entirely to the handling of radium. Similarly, the work of the Federal Government in atomic energy was undertaken with a full knowledge of the danger. The vast control program adopted has limited the injuries to a few unforeseen accidents. The subsequent expansion of the private industrial uses of radiation has been carefully controlled in the same spirit and the real hazard is minimal. The explanation of this excellent record lies in the effectiveness of "planned-in" safety measures. The dangers were recognized almost immediately by scientists competent and willing to control them. No vested interest in unsafe methods existed to delay adequate control. The one exception to both these conditions was in the handling of radium and this was where the major injury occurred.

Another principle learned was the necessity and effectiveness of accurate measurement of the noxious agent. The ability to detect and measure minute amounts of radiation greatly facilitated the development and maintenance of equipment and procedures to minimize exposure.

The industrial experience also demonstrates that awareness of the hazard, motivation for its control, and accurate measuring devices made control feasible by even the most rigid criteria. Data from the Atomic Energy Commission, reports on the evaluation of particular hazards, and a statewide report on the use of radiation in private industry bear this out. The record for the other great source of occupational injury, the medical use of x-rays, is not quite so good. Although radiologists have made invaluable contributions to the study of the effects of radiation and the development of general standards of performance and their application within their own field, there is evidence that the principles they have helped to create are not always rigidly adhered to. Nonradiologists, including dentists, have been the principal offenders in this respect. Although frank injuries are now unusual, overexposures are not uncommon.

PROBLEM AREAS

Despite the excellent record for the safe industrial use of radiation and the general slow improvement in its safe medical use, certain problems remain in the control of occupational sources of radiation. Their importance may be expected to increase as the use of radiation becomes more varied and intense. The very small doses which are taking on significance in view of the genetic effects present a double administrative problem. The larger aspect of the problem is to develop a workable and reliable means of measuring and recording the exposure of individual workers. Since certain uses require brief exposures beyond the acceptable maximum for a few people, the exact exposure relative to their own lifetime dose and their contribution to the population dose must be known so that further exposure can be terminated at the appropriate time. This is particularly important since the genetic effect in a population implies that, in a

long-term sense, high exposure of one individual equals small exposures to many. A lesser aspect of the administrative problem, but one of great practical importance, is the enforcement of minimum standards of radiation protection so that a few recalcitrant users may not undo the efforts of the virtuous. Again, the question of total population exposures reinforces the moral ground for requiring equal consideration for human values from all.

A psychosociologic problem in motivation is presented by the potential dangers from unforeseen accidents. Several such incidents have occurred, and in some cases it was apparent that familiarity with these potent agents had bred contempt. Controls were carelessly applied and even circumvented. The problem is how to maintain constant vigilance in applying the recognized control measures and how to develop additional methods to prevent or limit exposure from every conceivable eventuality.

The third great problem area, which is much broader than the occupational exposures, is that of research. The potentiality for good as well as ill in nuclear fission demands that dose-effect relationships be precisely delineated, including ranges as well as medians. This is necessary if atomic energy is to be used safely and efficiently. Some of these relationships have been worked out for animals and rough approximations are available for man in some cases, but detailed quantitation in man is urgently needed. The only solution lies in detailed epidemiologic studies, but these are made increasingly difficult by the need to restrict human exposure to the absolute minimum. Nevertheless, careful studies, such as those already done in children treated for thymoma and arthritic patients treated with x-ray to the spine, and other groups necessarily or accidentally exposed, will ultimately provide the answers.

VOL 9 195

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INDUSTRIAL NOISE AND HEARING LOSS

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OL.
9
959

INTRODUCTION

THE impression is general that noise-induced hearing loss is a new industrial development but, in fact, the deafness that accompanies work in noisy occupations has been known for over a century. Blacksmiths and boilermakers have long expected to suffer loss of hearing as a result of extended exposure to the noise of their occupations. During and shortly after World War II, industry expanded rapidly, high-speed machines were introduced, and production greatly increased. Uncontrolled industrial noise became more intense and occurred more frequently but little interest was shown either in noise control or in hearing conservation until 1947 when a large number of hearing loss compensation claims appeared in the state of New York and shortly thereafter in the state of Wisconsin. About this time also the American Academy of Ophthalmology and Otolarynology, the American Standards Association, and several scientific bodies of the military independently organized committees to investigate the problem. The reader will find specific information about industrial noise and hearing loss in references 1 through 24.

The specific causal relations of hearing loss to noise exposure are very complex and many questions are yet to be answered before definite statements can be made about how much hearing loss will result from a given noise exposure. It is known that long-continued exposure to intense noise can produce permanent inner-ear hearing loss, but the process of production is not well understood. The inner ear damage varies from minor changes in hair cell endings to complete destruction of the organ of Corti. What is the nature of the agent that causes this damage? Air-borne noise is a wave motion of air particles and is produced usually by vibrating bodies. This wave motion is made up of pressure fluctuations that move outward from the source of vibration at a speed of about 1,100 feet per second. Two aspects of the pressure wave are important to the production of noise-induced hearing loss: (1) frequency which is the number of fluctuations per second and (2) sound pressure level which indicates the magnitude of the fluctuations.

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The frequency of a sound largely determines its pitch. Frequency is measured in vibrations per second or cycles per second (cps). The young adult with normal hearing can hear sounds ranging from as low as 20 cps to about 16,000 cps. Higher frequencies are inaudible generally and are known as ultrasonics. (Fig. 1.)

Perhaps the most vital portion of the audible frequency range lies from 500 to 2,000 cps, the speech zone range. Hearing loss occurring in this frequency region is particularly important because it handicaps the person in communications with his family, friends, and co-workers.

Sound pressure level (SPL) is a measure of comparative amounts of sound. The sound pressure level of a noise is expressed in decibels (db). The decibel is a dimensionless unit based on the logarithm of the ratio of the sound pressure of the noise and a reference sound pressure.

Noise analysis includes the measurement of sound pressure levels of various bands of frequencies in the noise. The analysis is made with combinations of sound level meters, octave band analyzers, oscilloscopes, and other electronic apparatus. The SPL of representative sounds and an octave band analysis of one kind of noise are shown in Figs. 2 and 3.

VOL 9 195

EFFECTS OF NOISE EXPOSURE

The known effects of noise exposure are of two types: *nonauditory effects* which cause interference with communication by speech or which otherwise influence behavior and *auditory effects* which consist of temporary hearing loss and permanent hearing loss.

Nonauditory Effects of Noise Exposure.—Perhaps the best understood nonauditory effect is interference with communication by speech. Noises that are not intense enough to cause hearing loss may interfere seriously with communication by speech. If one must shout at very close range (6 inches or less) to communicate by speech, the noise is potentially hazardous to hearing.

The annoyance caused by noise is largely a psychologic response. Noises made by neighbors and their dogs tend to be more annoying than the same noises made by members of our own households. The annoyance caused by aircraft noise is intensified by the fear that the aircraft may crash onto us. In general, noises of higher intensity, high frequency (above 1,500 cycles per second) and/or intermittency tend to be more annoying, but there are large individual differences in reaction. Annoyance itself is not a health hazard and the fact that a noise is annoying does not establish it as a damage risk. Conclusions drawn from the most reliable tests of efficiency in performing mental and motor tasks under various conditions of noise exposure are that unfamiliar noise temporarily reduces efficiency, but that when an employee becomes accustomed to the noise his efficiency returns to a nonnoise performance level.

Certain temporary physiologic changes occur in the human body as a direct result of noise exposure. The usual emergency reactions of the body occur in response to sudden sharp sounds such as gunfire. A frequent recurrence of such reactions might impair health, but fortunately the magnitude of these physiologic responses wears off rapidly with repetition of the noise exposure.

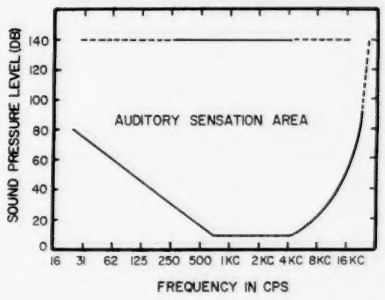

Fig. 1.—Range of Human hearing.

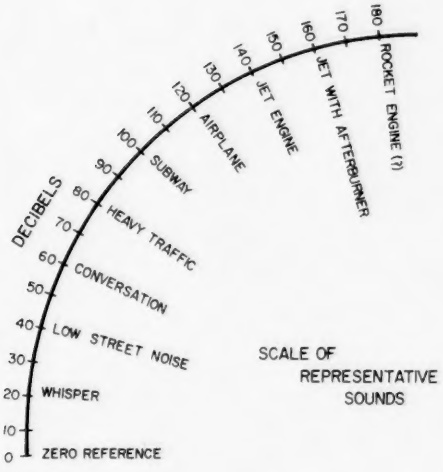

Fig. 2.—Representative sound pressure levels.

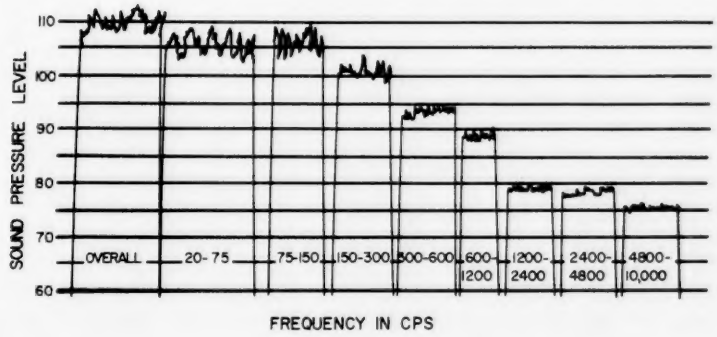

Fig. 3.—Octave band analysis of a noise.

Auditory Effects.—The auditory effects of noise exposure are of two types: temporary and permanent. The existence of temporary hearing loss, often called temporary threshold shift or TTS and of permanent hearing loss can be demonstrated easily.

Temporary hearing loss.—The term "temporary hearing loss" has become restricted by usage to mean either a temporary disability as defined by law or a hearing loss that results from one work day's exposure to noise and from which the ear has recovered usually by the next morning. Such temporary loss is found in many industrial employees at the end of a working day. Studies of temporary auditory threshold shift have made us aware of several important facts concerning both temporary loss and permanent loss. Some of these important facts are discussed briefly.

1. The amount of shift is different for different persons under the same conditions of noise exposure. Few persons have very large or very small shifts. The losses for most persons cluster around an average midway between the largest and the smallest shifts.

2. Temporary shifts produced by exposure to typical industrial noise are larger at the higher frequencies in the audible spectrum. Most of this temporary loss occurs in the frequency region between 3,000 and 6,000 cps.

3. Most of the temporary loss produced by typical industrial noise exposures occurs during the first one or two hours of exposure.

4. The larger the permanent hearing loss at any frequency, the less the temporary shift at that frequency.

The TTS produced by daily exposure to noise is important in practical considerations. For example, audiograms made during or at the end of a work day of noise will include temporary loss and so will not be a true indication of the amount of permanent hearing loss present. Industry requires a true measure of permanent hearing loss but it is quite impractical for all industrial audiograms to be made after a quiet period sufficiently long to eliminate temporary loss. We expect laboratory studies of TTS to result in a numerical method of correcting industrial audiograms for contaminating TTS.

Laboratory studies of TTS have demonstrated that continuous exposure and interrupted exposure produce different effects in the ear. If a noise follows a pattern of one minute "on" and one minute "off," for example, the amount of temporary loss is just half that which is produced when the same noise is on continuously. If a similar effect occurs for permanent hearing loss and if employees are allowed relatively quiet periods at intervals throughout the day, then long-term changes in hearing will be less than changes produced by continuous exposure.

Permanent hearing loss: Serial audiograms of persons exposed to intense noise show a characteristic progression of hearing loss. Early losses appear at frequencies between 3,000 and 6,000 cps (Fig. 4). Usually losses appear first at 4,000 cps and then in time spread in both directions until hearing for most of the audible frequencies is affected. The extent of the spread depends upon the amount and type of noise exposure sustained. Impairment of hearing is usually not noticed until the combined losses at the speech frequencies 500,

1,000 and 2,000 cps average more than 15 db (Fig. 5). Substantial losses may occur at frequencies from 3,000 cps to 6,000 cps without producing subjective awareness of changes in hearing. The production of noise-induced hearing loss

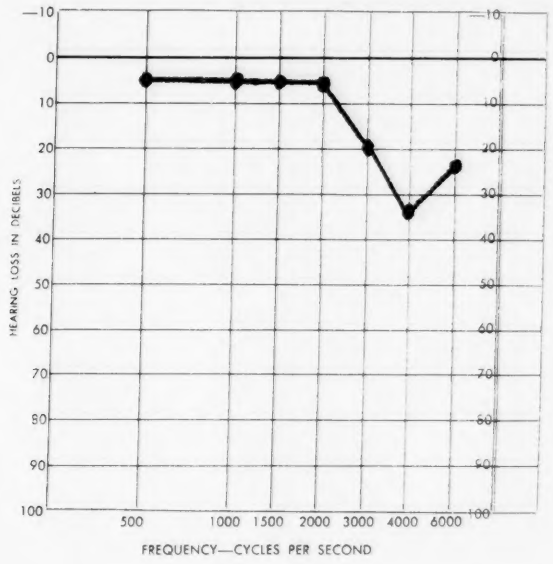

Fig. 4.—Early case of noise-induced hearing loss.

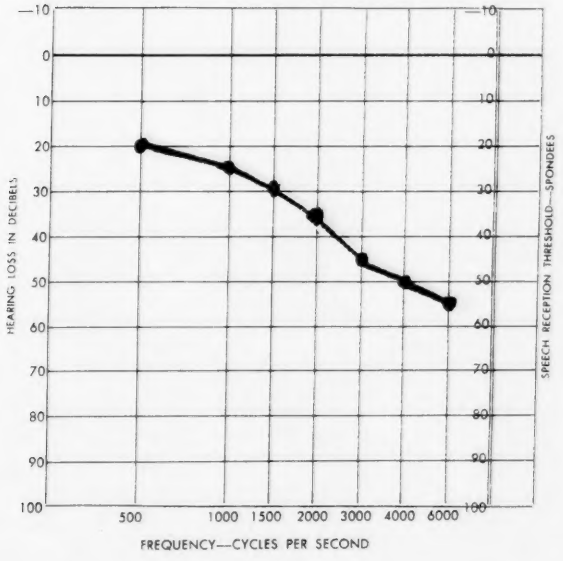

Fig. 5.—Hearing loss involving speech zone range.

is a slow and insidious process and years of exposure may elapse before any significant noticeable loss of hearing occurs.

The deleterious effects of noise exposure do not vary directly as the energy content of the noise. This means that a noise with twice the energy content will not produce twice as much hearing loss. The larger the total energy content of the noise the smaller the exposure time required to produce a hearing loss, but the mathematical form of the relation is not known.

Noise-induced hearing loss varies with (a) the type of exposure and its degree of intermittency, (b) the person who is exposed, (c) the total duration of the exposure, and (d) the use of ear protection.

Noise exposure and permanent hearing loss: Throughout the discussion we have referred to the hearing loss produced by *noise exposure*, not by noise alone. Brief exposures to most industrial noises will produce no illness nor damage to the ears. Any diagnosis of noise-induced hearing loss must be supported by adequate information about each of four factors of noise exposure: (1) the over-all noise level to which the man was exposed, (2) the frequency composition of the noise, usually as expressed in octave band sound pressure levels, (3) the duration and time distribution of noise during a typical work day, and (4) the total duration of noise exposure.

Brief exposures to over-all noise levels of 130 or 140 db will not produce severe or significant hearing loss. On the other hand, the possible effects of extended exposure to levels of 100 db must not be minimized. In many instances persons who are exposed to the 100 db noise have long total duration of exposure and existing hearing loss may well be noise-induced.

Some industrial processes show such rapid job turnover that the total duration of exposure for any man's ears may be not more than 2 or 3 years. Two or three years' exposure to the average industrial noise usually produces only minor changes in hearing.

This information pertains only to continuous noises. We know very little about the auditory effects of impact noises such as blasts, rifle fire, or drop hammer sounds.

CONSERVATION OF HEARING

Noise-induced hearing loss can be either prevented or greatly minimized through well-organized and properly monitored programs of hearing conservation. There are rules of thumb for assessing the possible need for a conservation program. Whenever persons have (1) difficulty communicating by speech when they are in the noise, (2) tinnitus after working in the noise for several hours, or (3) a temporary loss of hearing severe enough to muffle speech or other sounds, again after several hours of exposure, then the noise exposure is severe enough to warrant serious consideration of a hearing conservation program.

A hearing conservation program consists of three parts.

Analysis of Noise Exposure.—Four separate items are considered in an analysis of noise exposure; these are the same items listed previously. Knowledge of each of these items is important to the design of an effective program. Two noises may have the same over-all level, for example, and yet their frequency

compositions may differ so that one may produce a permanent hearing loss and the other may not. The daily duration and distribution of exposure may affect the severity of the expected loss; intermittent exposure is less hazardous than continuous exposure.

Control of Noise Exposure.—The amount of noise produced by the source may sometimes be reduced by changes in machine design. Also, mounting heavy machinery on shock-absorbing mounts tends to prevent vibrations from being transmitted through the floors and walls of the building. Enclosing noisy machines tends to prevent air-borne sound from reaching the ears of men who work in the machine area but who do not need to be near the machine itself. Sometimes, it is possible to revise operational procedures to convert continuous exposures into intermittent ones.

If complete environmental control is too expensive to be practical, control of noise exposure may be achieved through the use of personal protective devices such as properly fitted ear plugs or muffs or through a combination of environmental control and personal protection.

Measurement of Hearing.—Perhaps the most important part of a hearing conservation program is the measurement of hearing. The program should provide for preplacement hearing tests and for routine periodic follow-up or recheck tests. Preplacement tests provide reference or base line audiograms from which subsequent changes in hearing may be determined. These preplacement tests must be threshold tests. Air conduction threshold tests are sufficient. Thresholds are usually measured at 6 frequencies: 500, 1,000, 2,000, 3,000, 4,000, and 6,000 cps.

Threshold measurements at 3,000, 4,000 and 6,000 cps, sometimes called the monitoring frequencies, give a good indication of the status of hearing in the most sensitive region of the ear. Measurements at 500, 1,000 and 2,000 cps give an indication of the status of hearing in the all-important speech region. In the absence of valid speech tests to determine the handicap produced by hearing loss, the average of the hearing level at the three speech frequencies (500 1,000 and 2,000 cps) is used to estimate the hearing loss for everyday speech.[15]

Preplacement and follow-up tests help to identify persons who may be highly susceptible to noise-induced hearing loss. A series of follow-up tests made roughly at yearly intervals will tell whether or not the conservation program is effective. Follow-up tests of hearing may be screening tests. In some situations they may be single frequency screening tests. Details of the time-saving single frequency or limited frequency screening tests were recently described by Glorig and House in the *Journal of the American Medical Association*, April 5, 1958.

MEDICAL RESPONSIBILITY

Ultimately the responsibility for conservation of hearing rests with the physician. As stated in the *Guide for Conservation of Hearing in Noise* (published by the American Academy of Ophthalmology and Otolaryngology):

The conservation of any human function is primarily a medical responsibility. Hearing conservation is no exception. Prevention, diagnosis and treatment of hearing loss; validation and approval of audiometric records; and the final assessment of measurements of hearing are medical responsibilities. Any hearing conservation program without medical supervision must be considered inadequate.

Direct medical supervision of a hearing conservation program is highly desirable. Here a physician is responsible for the organization and administration of the testing program as well as for checking and evaluating audiometric records. The physician himself does not perform all the operations necessary to the conduct of the program; he delegates responsibility for many of the technical activities to members of his staff, setting up standards or limits within which they can operate semi-autonomously. Whenever medical records show that control of noise exposures may be inadequate, the physician in charge so reports. The responsibility for making necessary noise measurements and for effecting further environmental noise exposure control then devolves on the industrial hygienist, members of the engineering or safety departments or other persons assigned to the task. Although the actual operations of measurement and protection are performed by both medical and non-medical personnel, the physician ultimately is responsible for the health of the employee.

MEDICOLEGAL ASPECTS

Loss of hearing resulting from accidental industrial injuries previously has been recognized and compensated, but the claims arising from noise-induced hearing loss were met with surprise and resistance by industries and their insurance carriers. Alarmed and concerned, they felt that it was not the intent and the purpose of existing legislation to compensate for this type of hearing impairment. These claims were appealed to the Industrial Commissions and to the higher courts of the various states for interpretation of the provisions of existing compensation acts.

Decisions of the higher courts have been handed down in the states of New York[25-28] and Wisconsin[29] and by the Federal Courts of New York. These decisions have upheld the right of the worker to claim compensation for hearing loss arising from industrial noise exposure. Spurred by growing awareness of the effects of industrial noise upon hearing and by the decisions of various higher courts, many industries are showing an active interest in hearing. This interest is expressed in efforts to learn more about noise-induced hearing loss and in the establishment of industrial hearing conservation programs. Hearing conservation is perhaps industry's most significant step toward a solution of the problem.

Information about industrial hearing conservation is furnished to interested persons by the Subcommittee on Noise of the American Academy of Ophthalmology and Otolaryngology. Intensive research in all phases of the industrial noise problem, and particularly in the area of industrial hearing conservation, has been and is being carried on by the Subcommittee's research staff. Requests for information should be forwarded to the Director, Research Center, Subcommittee on Noise, 111 N. Bonnie Brae St., Los Angeles 26, Calif.

SUMMARY

Hearing loss resulting from industrial noise exposure is assuming increasing importance in our everyday life. It is the outgrowth of our rapidly expanding

industrial development. The industrial noise problem is a complicated one because it involves many technical and professional fields. While claims for loss of hearing resulting from noise exposure have brought this problem to the forefront certainly it is not the most important part of the problem. As physicians we believe that conservation and protection of human hearing is worthwhile and most important. With an understanding of the problem of industrial noise and with the cooperation of labor, management, and the medical and allied professions, conservation of human hearing in industry can be accomplished.

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VOL.
9
1959

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BERYLLIUM DISEASE

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VOL
9
195

THERE is a real need for physicians handling chronic illness to understand the available knowledge of intoxication following exposure to toxic beryllium compounds in harmful amounts. There are two reasons for this statement: First, in a remarkable number of cases there is a delay from the last beryllium exposure to the onset of clinically detectable disease. This period of delay is presently recorded to be as long as 15 years in a few cases. Since hitherto unknown cases are currently being discovered to be related to previous toxic beryllium exposure, the length of this "incubation period" may continue to increase. The second reason for increasing knowledge of beryllium disease arises from the fact that there is a continued increase in the use of beryllium and its compounds. The industrial need for beryllium compounds is such that often only small numbers of workers are exposed in a single operation. Since this is true, the difficulties of correct diagnosis are increased by the fact that the sick worker may fail to mention or may be ignorant of harmful beryllium exposure.

HISTORY

Knowledge of human illness arising from industrial exposure to beryllium compounds came first from Germany.[1] Two years later, in 1935, Fabroni,[2] working in the Industrial Clinic in Milan, Italy, reported a disease produced in animals exposed to certain beryllium compounds which he chose to call "berylliosis." Gelman and his colleagues[3] in 1936 presented a report from Russia on certain ill effects of beryllium on the skin and the respiratory tract. Gelman's observations were made on workers who used fluoride compounds of beryllium in the extraction of the element from the ore. He believed that the illness he saw might be due to the presence of the fluoride radical in the worker's exposure. In 1940 Berkovitz and Israel,[4] after observations made in Russia, reported on 46 cases of illness from the same industry and called the disease "beryllium fluorine intoxication." Two years later Meyer[5] in Germany discussed what he considered to be a new lung disease in workers engaged in extracting beryllium.

In 1943 Van Ordstrand and his colleagues[6] described a chemical pneumonia in Ohio workers employed in extracting beryllium from beryl ore. The reports

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that have come from America since 1943[7-11] all show that beryllium or one of its compounds is the common denominator in the industrial exposure[12] of workers with respiratory tract disease variously called beryllium poisoning, berylliosis, or delayed chemical pneumonitis.

Because of the great expansion in the manufacture of fluorescent lamps which took place in the United States in the late 1930's, many workers were exposed to phosphors containing beryllium. The phosphors contained zinc manganese beryllium silicate in most instances, although there were variations in composition from company to company; the amount of beryllium varied from about 2 per cent to as much as 14 per cent. In 1944 Kress and Crispell[9] described an atypical pneumonia occurring in workers engaged in making fluorescent powders. These men were said to be exposed to beryllium carbonate and beryllium manganese silicate. Their illness was similar in some ways to certain infectious pneumonias and in some respects resembled the European description of lung disease in workers exposed to certain beryllium compounds. In 1958 the Beryllium Case Registry[13] reported 601 cases of illness in the United States considered due to exposure to toxic beryllium compounds. New cases, although not in large numbers, continue to be reported, suggesting that beryllium disease is a current diagnostic problem.

OL.
9
959

USES OF TOXIC BERYLLIUM COMPOUNDS

In order to make a correct diagnosis of chronic beryllium disease, it is necessary to consider occupational and neighborhood exposure to toxic compounds of this element. Since the delay in onset in a few cases is now known to exceed 10 years, the chief problem is to consider beryllium exposure in taking the history of patients with miliary chest disease.

Until recently, extraction of beryllium from the ore, beryl, and the manufacture of fluorescent lighting were correctly considered the chief sources of cases of beryllium poisoning. The list of sources has lengthened to include those industries and industrial operations listed in Table I. Recent increase in interest in beryllium for airplane structure and gyroscopes, as well as its use in nuclear reactors, means that there will be continuing potentially dangerous exposures to this important element in operations without adequate control.

TABLE I. INCRIMINATED BERYLLIUM-USING OPERATIONS

Extraction of beryllium	Beryllium metallurgy
Fluorescent powder manufacturing	Ceramic operations
Fluorescent lamp manufacturing	Radio tube manufacturing
Fluorescent lamp salvage	Atomic energy development
Neon sign manufacturing	Neighborhood contamination
Beryllium alloy manufacturing	Use of alloys containing more than 4 per cent beryllium

To elicit a history of toxic beryllium exposure may not be easy, since the patient is often ignorant of the materials with which he has worked, or his description of his job may be unintentionally misleading. Any beryllium-using

operation which results in air-borne and respirable material is potentially hazardous, since inhalation is the mode of entry of the toxic material. Operations which involve high temperatures, shaking beryllium-containing powders, or machining should be suspected. Of the 40-odd cases of neighborhood beryllium disease, over half were exposed to the fine dust from workers' clothes brought home heavily contaminated from factories where beryllium was formerly thought harmless. Of the remaining cases, all but a very small number lived in close proximity to beryllium-using plants which took no precautions against contamination of neighborhood air. Studies are currently in progress to increase knowledge of the mechanism of production of neighborhood beryllium poisoning.

Present evidence indicates a variation in toxicity of beryllium compounds, depending upon physical or chemical characteristics not now defined. In addition, there are the usual problems of variation in host response to insulting material, comparable to variations in response to potentially harmful doses of lead or silica. These points are made to emphasize the need for a careful occupational history to discover qualitative and quantitative data describing beryllium exposure when a clinical syndrome suggests the diagnosis of beryllium disease. Industry, government agencies, and insurance companies can assist a physician who is uncertain of the assessment of a beryllium exposure.

VOL. 9 195

CLINICAL FEATURES AND COURSE OF BERYLLIUM DISEASE

Based on the course of the disease, two general syndromes of beryllium poisoning have been described—the acute and the chronic. To present these clinical pictures, material from the Beryllium Case Registry has been utilized. In analyzing the material in the Registry, an illness lasting over a year has been considered a chronic case. Table II shows that 61 per cent of the cases from the Registry have a chronic illness, and these are equally divided between men and women. The remaining were acute cases in which men predominated. These differences may only reflect the employment practices in the industries where intensity of exposure varies, although there is suggestive evidence that women are more susceptible than men to chronic disease. Included in both the acute and chronic cases were 28 patients who did, in fact, have both acute and chronic beryllium disease. These were patients whose acute illness resolved and in whom a chronic disease appeared later without necessarily any additional exposure.

TABLE II. BERYLLIUM REGISTRY CASES

	ACUTE	CHRONIC
Male	227	191
Female	20	191
Total	247 (39%)	382 (61%)
Dead	15 (6%)	121 (31%)

Acute Beryllium Poisoning.—Early case reports from Germany[1] and later from the United States[6] contain excellent descriptions of the acute illness. The major clinical manifestations, dermatitis and/or irritation of part or all of the respiratory tract, depend upon the intensity and type of exposure. Conjunctivitis may also be associated with the dermatitis.

The dermatitis may be (1) contact dermatitis, (2) a localized skin ulcer, or (3) a subcutaneous granuloma. The contact dermatitis has been described as a papulovesicular reaction, occurring on the exposed parts, and subsides on removal from exposure. The skin ulcer develops after the accidental introduction of a crystal of beryllium salt. It does not heal readily without curettage of the ulcer base in which the crystal is embedded. Subcutaneous granulomas have been reported weeks to months following abrasion with fluorescent lamps.

More dramatic may be the respiratory tract manifestations, ranging from mild nasopharyngitis to tracheobronchitis and even fatal pneumonitis. Six per cent of the acute cases in the Registry died during this phase of their illness. The symptoms of this pneumonitis are anorexia and remarkable weight loss, cough (usually nonproductive), shortness of breath, and chest discomfort, with muscular fatigue caused by breathing. Cyanosis, tachypnea, orthopnea, and the signs of diffuse lung involvement may be noted on physical examination in the severe cases. Chest x-rays show bilateral patchy and nodular densities, at times confluent, not unlike those seen with bacterial and viral bronchopneumonias or with pulmonary edema. Pleural effusion has not been found, although pleural friction rubs may be heard. Symptomatic remission usually precedes x-ray improvement. Clearing of the x-ray occurs in weeks to several months. Death has been due to the extensive pneumonia.

Chronic Beryllium Poisoning.—As previously mentioned, a few patients with acute beryllium poisoning apparently recover and later develop a chronic disease. However, the majority of patients develop their disease several weeks to years after their last exposure and give no history of an acute illness. Table III summarizes the latent period between the last exposure and onset of symptoms. Forty-one per cent of cases begin within a month of their last exposure. A substantial number appear 1 to 5 years (29 per cent) and 5 to 10 years (18 per cent) after exposure. The longest interval to date is 15 years. The duration of the exposure has usually been more than 2 years (Table IV).

TABLE III. TIME FROM LAST EXPOSURE TO FIRST SYMPTOMS

	NUMBER OF CASES	PER CENT
Less than 1 month	126	41
1 month to 1 year	27	9
1 to 5 years	89	29
5 to 10 years	56	18
More than 10 years	12	4
Total	310	101
Maximum: 15 years		

TABLE IV. DURATION OF EXPOSURE TO BERYLLIUM

	NUMBER OF CASES	PER CENT
Less than 1 week	1	0.3
1 to 10 weeks	18	5.5
11 to 100 weeks	102	31.1
More than 100 weeks	207	63.2
Total	328	101.1

There are clinical features of the chronic disease that indicate a widespread process. Pneumonitis is the most familiar and striking, but skin nodules, hepato- and splenomegaly in the absence of congestive failure, and renal stones have all been reported. Skin granulomas appear spontaneously in a few patients no longer exposed to beryllium. On biopsy, beryllium is found in the tissues. The onset of pneumonitis is often precipitated by some acute stress. This may be pregnancy, viral respiratory infections, sudden weight loss with dieting, thyrotoxicosis, surgery, or the inhalation of fumes. Forty per cent of the women with chronic disease who had become pregnant after beryllium exposure experienced the onset or increase of symptoms with pregnancy or during the immediate postpartum period.

The most common symptoms were dyspnea on exertion and cough, usually nonproductive. Weight loss, with or without anorexia, weakness, and fatigue were prominent. Chest pain was noted in nearly one-third. This pain may be typically pleuritic or may be the muscular discomfort of labored respiration. In a few cases unexplained febrile episodes have occurred. Nine asymptomatic cases were included on the basis of x-ray findings, positive beryllium assays, and history of exposure.

There may be few signs in a patient at rest. In progressive cases cyanosis, clubbing, muscular wasting, and tachypnea at rest may be obvious. Chest findings may be minimal or may include bronchovesicular breath sounds with transient râles, friction rubs, and limited chest expansion. Expiration is not prolonged as in the patient with advanced emphysema. Hepatosplenomegaly may be noted when these organs are involved or when congestive failure ensues. Orthopnea occurs with the onset of heart failure.

Chest roentgenograms show a diffuse involvement of the lungs with discrete miliary nodular densities. Hilar adenopathy may be present. The picture is not specific and must be differentiated from other granulomatous diseases.

Laboratory findings have shown alteration in the serum proteins with elevation of globulins. Systematic study with electrophoresis shows that the gamma globulin fractions are elevated. Alteration in "liver chemistries" occur with involvement of this organ. Hypercalciuria has been noted in patients whose course is complicated by renal stone and in several in whom no stone has appeared. The hypercalciuria cannot be attributed to negative calcium balance of acute loss of bone tissue (osteoporosis) from disuse or steroid therapy. Bone disease

VOL. 9 1959

of this type has not been observed and the observation of hypercalciuria antedated the use of steroids. Another mechanism such as increased absorption may possibly be responsible. Patients studied by means of metabolic balance techniques have shown negative nitrogen balance. Arterial hypoxemia with or without accompanying polycythemia may be found as a manifestation of the increased alveolar-arterial gradient found in the disease. This has lead to the description of beryllium disease as one of the causes of the "alveolar-capillary block" syndrome. With advanced cases there is reduction in the maximum breathing capacity and still later minor ventilatory changes compatible with emphysema.

Diagnosis.—In most cases the diagnosis of beryllium disease is made by establishing significant exposure to toxic beryllium compounds in one of the clinical syndromes described here. The finding of beryllium in the urine or tissue in cases of granulomatous disease makes the diagnosis certain.[14] The patch test of Curtis[15] when positive supports the diagnosis. Uncertainty remains in a few cases. The methods of beryllium assay when small amounts are involved are difficult, and few laboratories are experienced in such assay. Clinically, some cases of chronic beryllium poisoning mimic pulmonary sarcoidosis so closely that if relationship to beryllium exposure is not readily established, the correct diagnosis may be very difficult to make.

Course and Prognosis.—Two major complications occur in chronic beryllium disease: spontaneous pneumothorax (12 per cent) and renal stones (10 per cent of those in whom data were considered adequate). Tuberculosis is striking by its near absence. There have been only 4 patients with chronic beryllium disease from whom tubercle bacilli have been obtained by culture or guinea pig inoculation. Of 104 tuberculin tests reported, 24 per cent have been positive. Progressive pulmonary disease has resulted in disabled respiratory cripples who die in congestive heart failure due to cor pulmonale. The mortality has been previously noted in Table II. It is also summarized in Table V, listing the number dead among the several groups with varying delay between exposure and onset. The results suggest that the course of the disease is more benign in those with a late onset of symptoms. The exact factors which may be responsible for this (lesser exposure, treatment with steroids, etc.) cannot be determined.

Mortality figures alone do not give a picture of the effect which a chronic disease has on the patient. Neither do morbidity nor prevalence rates. Information on the actual condition of the patients afflicted with the disease is incomplete

TABLE V

DELAY BETWEEN EXPOSURE AND ONSET OF DISEASE	NUMBER DEAD/TOTAL IN GROUP	PER CENT
Less than 1 month	49/126	39
1 month to 1 year	10/27	37
1 to 5 years	29/89	32
5 to 10 years	10/56	18
More than 10 years	0/12	0

from the Registry. However, our personally observed series of 55 patients was reviewed for working status. Nearly one-half are working. Some of these patients are under long-term steroid treatment. Of the remaining nonworking group, 22 are ambulatory, two are confined to a bed and chair, and two are bed patients. Survival with the disease has left only a very few asymptomatic and many with diminished respiratory reserve and disabling symptoms.

Pathologic Changes of Beryllium Disease.—At high doses of exposure to harmful beryllium compounds, a specific fibrinoid pneumonitis with considerable edema has been seen in the few autopsied cases. Toxic beryllium compounds when inhaled in harmful quantity produce, in the chronic form, an inflammatory response which is difficult to distinguish from the changes seen in Boeck's sarcoid. The characteristic lesion reported is a noncaseating granuloma in which beryllium may be demonstrated. In addition there is considerable round cell infiltration as part of the inflammatory response to beryllium insult. Although the lung is most frequently involved in beryllium disease, liver, spleen, kidney, hilar, and abdominal nodes, heart muscle, and striated muscle may also be affected. The amounts of beryllium found in diseased tissue may be small, even as low as the sensitivity of the spectrographic method of assay, which is 0.003 mcg. per gram of tissue. It is clear that the amount of beryllium found is not correlated with the extent of pathologic change.

There is considerable speculation as to the mechanism of production of detectable disease following toxic beryllium exposure, especially in those cases where there is a long delay between exposure and clinical illness. Experimental animal studies, as is often the case, have produced perplexing and inconsistent results. Granulomatous lesions of lung, liver, and subcutaneous tissue have been reported in some animals by some observers. All who have tried find that osteogenic sarcomas can be produced in rabbits with beryllium compounds. Lung malignancy has appeared in significant numbers in experiments with at least one laboratory animal exposed to a beryllium compound. Thus far, there has been no evidence of beryllium-induced malignant disease in humans. However, since the clinical picture of beryllium disease is still unfolding, it will be some time before all the possibilities of toxic beryllium effect have been detected and accurately recorded.

THERAPY

Until the steroids became available, the treatment of chronic beryllium disease was purely symptomatic. The use of oxygen with and without intermittent positive pressure breathing devices controlled the serious dyspnea of such patients to a remarkable degree. Such therapy may still be useful in an occasional case during a surgical episode, a serious infection, or a pregnancy. Long periods of bed rest were tried. Because of the cough, dyspnea, and in some cases repeated respiratory infections, patients were taken to warm climates or to high, dry places in Arizona, with some temporary symptomatic relief but no detectable change in the course of the disease.

VOL. 9 1959

By 1951 a few cases of beryllium poisoning had been studied before, during, and after intensive treatment with ACTH.[16-18] There was both subjective improvement of the patient and objective change in abnormal cardiorespiratory function. As oral steroids became available, they were used at various dosage levels, given steadily and, in some cases, tried with occasional periods of ACTH therapy. Current evidence is good that steroids given in adequate doses will influence the clinical course of chronic beryllium disease favorably. Lesions of the skin, enlargement of spleen, and such abnormalities as hypercalciuria, will disappear. The most important consistent finding is that the oxygen unsaturation caused by the marked changes of beryllium poisoning is reversed to a remarkable extent, accounting for the clinical improvement. It appears that wise and continued therapy with steroids will change for the better the patient's clinical course, but it is not yet possible to speak of a cure of beryllium disease with steroids. Remarkably few serious side effects have been reported in series of cases given such drugs over periods as long as 5 years. In our experience, only once has it been necessary to stop using steroids because of evidence of gastrointestinal symptoms.

L.
959

PREVENTION OF BERYLLIUM DISEASE

That correct steps have been taken to prevent further harmful beryllium exposures is shown by the fact that of the 601 cases of beryllium disease in the Registry, all but 10 had their exposure before 1950.

The single most important step in controlling beryllium disease was taken by the fluorescent lamp manufacturers who in 1949 agreed to discontinue the use of beryllium in its phosphors. Unfortunately, since neon signs can be made on a very small scale and beryllium compounds are easily obtainable, there continues to be hazardous beryllium exposure in the manufacture and repair of neon lighting. In addition, it is well to emphasize that because of the delay between the last beryllium exposure and the onset of clinically detectable illness, cases of beryllium poisoning are currently being diagnosed in workers manufacturing fluorescent lamps.

Since it was necessary to use beryllium in the early days of atomic energy development, engineering control of beryllium exposures was carefully worked out by industrial hygienists working with the Atomic Energy Commission. On the basis of human experience and animal studies, tentative levels considered safe for long-term exposure were suggested by a committee advising the Atomic Energy Commission. The figure of 2 micrograms M^3 air for an 8-hour day was proposed in 1949. At this writing, there is no evidence that disease has resulted following exposures at this level. Indeed, the figure may be too conservative, but the prognosis of the chronic disease is such that no one is inclined to propose that the level be raised.

A few laboratories practice complete enclosure of beryllium operations. In urban communities the beryllium which might contaminate the atmosphere is collected. Large plants have moved to areas of sparse population and utilize carefully calculated stack height to eliminate neighborhood beryllium poisoning.

In very short duration beryllium operations, respirators supplied with outside air are used.

Medical control consists of excluding from beryllium exposure workers with previous attacks of beryllium disease and those with detectable respiratory disease. Preplacement medical examinations should include 14 by 17 chest x-rays, so that, in the event of accidental exposure, earlier abnormalities may not result in a false diagnosis. Except for medical follow-up of clinical complaints or check-up after overexposure, routine examinations have not been helpful in control of beryllium poisoning. However, ideal medical control includes annual medical check-up to record interval history of respiratory disease and evaluate symptoms of weight loss and mild dyspnea as early evidence of beryllium effect.

Beryllium compounds are extremely useful. If adequate attention is paid to control of hazardous exposures, there is no presently known reason why industry should not continue their use without fearing that job-related illness will occur.

VOL 9 195

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ECONOMIC POISONS IN RELATION TO MAN'S HEALTH

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OL.
9
959

CHEMICALS having toxic properties that are utilized in agriculture, industry, and commerce are sometimes called "economic poisons." Their function is to increase quantity, improve quality, and promote acceptability of an ever-expanding array of commodities offered to the consumer. Farming is the one segment of the economy where almost all of these poisons can be found and where their usefulness has been exploited most fully. Nonagricultural applications of the economic poisons are less generally appreciated but contribute increasingly to our daily lives.

THEIR SCOPE

The advances in scientific farming in the past 20 years constitute the beginnings of a technologic revolution that holds as much promise of benefit to mankind as does the development of atomic power. Much of the recent progress in agriculture can be traced to the development of two classes of chemicals, namely, herbicides and plant growth regulators on the one hand and pesticides and pest repellants on the other. Both groups are sometimes spoken of collectively as "pesticides." Over 200 distinctly different substances are now marketed in thousands of varied pesticidal formulations.

Many vermin in addition to crop-destroying insects are giving ground in the face of this multivalent chemical assault, notably mites, chiggers, spiders, nematodes, slugs, ticks, snails, and rodents of many kinds. Fungicidal chemicals are now available as sprays and dusts to attack the myriad blights, mildews, scabs, and rots that attack our food and forage crops. Crops and crop-bearing soils are not the only sites appropriate for the application of agricultural poisons. Germicides and disinfectants are employed routinely in almost every dairy barn and in many other farming operations as well. Livestock losses from external parasites are being reduced by spraying, dipping, and dusting farm animals with a variety of insecticides and repellants. Seeds and harvested produce in storage are often protected by fumigants and by the strategic placement of poisoned bait. Control measures against some agricultural pests are unsuccessful when limited to the farm. In an attempt to halt the fire ant infestation spreading from an original focus on the Alabama coast, entire counties of several Gulf Coast states have been blanketed with dieldrin sprayed from airplanes.

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Of course, not all of these economic poisons are new.[2] The insecticidal potency of nicotine was recognized and employed before 1690. Rotenone sources such as derris grown in Malaya and the East Indies and cubé from Central and South America have been used for centuries to poison arrowheads used in hunting game and to poison fish for collection as food. Pyrethrum has served as an insecticide for many generations. Lime sulfur and Paris green were developments of the mid-nineteenth century. The Bourdeaux mixture (prepared from lime and copper sulfate) was announced in 1885 as a successful agent against mildew in the grapevines of the Medoc region. The chlorination of municipal water supplies comes to mind as another example of a comparatively early (1908) and effective economic poison. The great majority of pesticides in current usage, however, were unknown until their synthesis within the past quarter-century.

So successful have these economic poisons been on the farm that they are now in demand by those engaged in many nonagricultural vocations and avocations. Most military experts regard them as part of the indispensable impedimenta of a modern army. Highway and park departments, railroad lines, and power companies make extensive use of weed and brush killers, defoliants, desiccants, soil sterilants, and other types of herbicides to keep their respective right of ways free from overgrowth. Rodenticides are generally accepted as an important element in rat control at municipal dumps. Golf courses employ these same substances against their special enemy the mole. Products made out of leather, paper and wood, canvas and other textiles, certain types of electric insulation, and other materials that are readily attacked by fungi and molds are now being treated with chemicals to prevent this type of deterioration before the product is sold to the consumer and sometimes even before the raw material is fabricated. Several modern paint formulas include pesticides of long persistence. Almost everyone who produces, processes, markets, or serves food has occasions to employ disinfectants, germicides, and sanitizers. Swimming pools and ponds are being treated with algicides. Conservationists, who at one time were the most uncompromising opponents of those who would interfere with the balance of nature, are now using chemicals to attack selectively the predators of game fish and game animals. Even the state of Vermont, which has long encouraged its hunters to kill porcupines, is no longer collecting porcupine ears in return for a bounty; instead arsenic-poisoned apples are being rolled into the winter dens of this destructive rodent. Surely the age of chemistry is here!

Industry and government are not the only nonagricultural users of economic poisons. In modern suburbia the amateur gardener who expects accolade from his neighbors must know how to use modern garden chemicals and be able to discuss their relative merits. The lawn has become a favorite target for multiple chemical applications. Persons who have long hated cats and dogs are now finding some measure of relief by the intensive use of animal repellants around the home. Surely it must be hard to find a house in this country that has not been sprayed on the inside or outside with an insecticide. Even rooms that have escaped "knock-down" aerosol bombs are likely to have furnishings, such as drapes and rugs, that have been treated with moth-proofing chemicals either by the manufacturer or a professional dry-cleaner. In the same way that most of us no longer tolerate vermin in our homes, we now expect chemical protection

VOL 9 195

out-of-doors as well. It is not uncommon to find someone trying by vigorous spraying to establish a pest-free domain outdoors, such as a patio or unscreened porch. An insect repellant for the skin is becoming a standard item in the vacationist's paraphernalia.

THEIR ROLE IN MEDICINE

That the recent development and utilization of this host of economic poisons has already had an impact on the health of man is widely recognized. It is worthwhile, however, to examine some medical implications of this achievement and to explore its promise for the future. The most obvious contribution of the economic poisons to human welfare has occurred in the field of preventive medicine.

A variety of insecticides has been pressed into service to combat insect and other arthropod vectors of human disease. DDT has proved to be the most successful of these chemical munitions. A delightful and informative account of DDT's triumphs has been contributed by Rice.[9]

DDT's first large-scale victory occurred in Naples after General Mark Clark's Fifth Army entered the devastated city on Oct. 1, 1943. Twenty-five cases of typhus were observed in Naples during October, 42 in November, and 60 during the first half of December. Thereafter the number of new cases rose sharply, and 45 were reported on Christmas Day alone. On December 26 a state of epidemic was proclaimed by the Fifth Army, and drastic regulations were instituted. As usual in such situations, public places of assembly, such as restaurants, barber shops, and theaters, were closed, and the metropolitan area was declared off-limits to all but essential military personnel. A gigantic offensive was launched against the body louse. For the first time a body dusting powder containing DDT was issued. Using newly developed hand blowers, two-man teams dusted soldiers, their clothing, and bedding, at the rate of 40 men per hour; the civilian population was treated similarly. This mass delousing program continued into March. It was too late to prevent the 800 new cases of typhus that appeared in January, but by February the incidence was lowered markedly, and in March the epidemic ended.

The use of DDT as a mosquito larvicide and a mosquito spray lagged behind its development as a louse powder, probably because the fatality rate in typhus fever is higher than that in any mosquito-borne disease. It was not long, however, before it proved its effectiveness against the malaria and filariasis-bearing Anopheles and the yellow fever and dengue-bearing Aedes. Military experts agree that without this insecticide the morbidity from dengue and malaria would have severely jeopardized the American campaigns in the Philippines, Mariannas, and Okinawa.

After the war DDT performed even more remarkable miracles. It all but eradicated malaria in the formerly endemic areas of our southern states, Cyprus, Greece, British Guinea, and Venezuela. Its incidence was markedly reduced in India, Pakistan, Ceylon, Thailand, and essentially everywhere else where it received a large-scale trial. Perhaps the most spectacular and one of the best documented cases of mass spraying with DDT was carried out by the Italian government between 1946 and 1949 on the island of Sardinia. Of the 1,250,000

inhabitants of Sardinia, about 75,000 suffered from malaria each year, of which 10,000 were new cases. By 1951 only 3 new cases were discovered, of which only one could be attributed to a mosquito.

While no other substance can equal DDT's record in the prevention of human disease, several poisons of economic value in agriculture and industry have also found a role in modern medicine. A measure of this influence can be gleaned from the listings in the most recent edition of the *Pharmacopeia of the United States* (U.S.P. XV, 1955). As in the earlier edition (1950), DDT occupies a well-deserved place under its official name of chlorophenothane. The gamma isomer of benzene hexachloride was added to the fifteenth edition as a scabicide; benzyl benzoate and sulfur are also recognized officially as scabicides. The fungistatic agents admitted to the U.S.P. XV are methylparaben, propylparaben, undecylenic acid, and its zinc salt. The list of local anti-infectives and disinfectants includes both old and new substances: phenol, cresol, ethyl alcohol, iodine, ammoniated mercury, mercury bichloride, silver nitrate, chlorobutanol, and benzalkonium chloride. In addition methylrosaniline chloride (gentian violet), benzethonium chloride, bithionol, and hexachlorophene are new listings in the *Pharmacopeia*. Official insect repellants suitable for application on the skin consist of butopyronoxyl, dimethylphthalate, and ethohexadiol. Sodium fluoride is now included because of its role as a prophylactic agent against dental caries. Of the 163 items dropped from the *Pharmacopeia* in its last revision, only one can be reasonably classified as an economic poison. It takes no great insight to predict that the next *Pharmacopeia* will recognize several more poisons that are of value in both medicine and commerce.

VOL. 9 195

THEIR CONTRIBUTION TO MAN'S FOOD SUPPLY

The urgent need to expand world food production to match the explosive increase in population is a second area in which the economic poisons have and will continue to benefit mankind. Considering the many allegedly conservative reports that more than one-half of the world's human inhabitants now exist at or near a starvation level of subsistance,[7] one can safely predict that even a modest expansion in the per capita production and distribution of food will lead to a dramatic improvement in the general state of health. Current and future economic poisons can be depended upon to play an important role in this mission.

Of course, pesticides represent only part of the improved technology of modern agriculture. From a world-wide point of view, fresh water for irrigation is undoubtedly a more important requirement than are pesticides. The sale of chemical fertilizers in the United States is about five times greater than that of agriculturally useful poisons. Pesticides, however, represent the most rapidly expanding branch of the agricultural chemicals industry; Fischer[2] reports that 260 million dollars worth of them were sold in the United States in 1954. By 1975 it is estimated that the annual pesticide market will reach one billion dollars or almost one-third the total value of all agricultural chemicals.

That such huge sums of money can be spent profitably on pesticides is a reflection of the enormity of economic losses caused by farm pests. For example, an annual loss of eleven billion dollars in the food and fiber harvests has been

traced to weeds, fungi, insects, and other pests.[2] More than 25 per cent of this damage is due to insects alone, with 5,000 different kinds contributing to the carnage. Almost another billion dollars represents domestic livestock losses from animal pests. Of the 260 million dollars spent to combat this destruction in 1954, 26 per cent went for insecticides, 32 per cent for fungicides, 13 per cent for herbicides, 8 per cent for miticides, and the remaining 11 per cent for soil and space fumigants, rodenticides, repellants, and others.[2]

The magnitude of the present problem should not obscure the very impressive measure of success that has attended recent efforts to solve it. Our current national population of 175 million persons is better fed today than the 106 million citizens of 1920, although the harvested acreage of farmlands has remained almost constant at 350 million acres. It is generally recognized that four factors have contributed to this increased farm productivity: namely, pesticides, fertilizers, farm mechanization, and improved varieties of plants and breeds of animals. Fischer[2] says that these four factors have contributed about equally to the rise in agricultural production efficiency in this country.

OL.
9
959

THEIR RECORD IN ACCIDENTAL POISONINGS

Aside from the meritorius services performed by the economic poisons, their extensive use has created at least one situation that is lamentable. Perhaps it is inevitable that readily available chemicals will be misused or incautiously used by substantial numbers of intemperate people. The inherently high toxicity of the pesticides makes their abuse particularly disastrous, as evidenced by the number of severe human poisonings that have attended acute exposures. In the decade from 1946 to 1956, economic poisons in the United States caused between 100 and 200 accidental deaths each year, representing approximately 10 per cent of the fatalities associated with accidental poisoning by solid and liquid substances.[1]

As the incidence of serious poisoning rose among farmers at the end of World War II, many individuals and organizations expressed concern and even alarm. In 1947 Congress passed the Federal Insecticide, Fungicide, and Rodenticide Act, which prohibits from interstate commerce any unregistered or improperly labeled economic poison. In order to register a product the manufacturer must reveal to the Department of Agriculture its complete composition, claims made for its efficacy, and the evidence on which these claims are based. The label must also state fully the composition and carry the word "poison" when appropriate, together with suggestions about the proper first aid in the event of accidental poisoning. To aid in implementing this law, the Association of American Pesticide Control Officials was organized in 1946. This organization, together with the National Agricultural Chemicals Association, the National Pest Control Association, and other groups, has provided needed technical information to both manufacturers and consumers of economic poisons. The effort to educate the farmer in the proper and safe use of these substances has been and continues to be intensive.

In the meantime the U.S. Public Health Service, particularly through its Technical Development Laboratories at the Communicable Disease Center in

Savannah, Georgia, collected and is still collecting information about toxic hazards to man by analyzing both laboratory and field data. The American Medical Association organized its Committee on Pesticides to study health problems associated with the use of economic poisons. This group has been particularly instrumental in alerting the medical profession to pesticide hazards and to methods of preventing and treating poisonings from these agents.

While it is not clear how successful these educational programs have been, remarkably few deaths from occupational exposure to economic poisons are reported currently in the United States.[1] With respect to nonfatal occupational poisonings, the situation is less clear. In the state of California, where the records appear to be most complete, pesticides accounted in 1955 for 7.8 per cent of all injuries to agricultural workers or 1.9 per cent of all occupational injuries. Several classes of chemicals were citied as more frequent offenders than the economic poisons, but poisonings due to the latter tended to be more severe.

The record with respect to nonoccupational exposures is not nearly so satisfactory. The home continues to be the most common place for accidental poisonings due to pesticides, and the most frequent victim is still the young child. Economic poisons were responsbile for 5 to 20 per cent of all the cases handled recently by 113 poisons centers scattered throughout the country.[1] In a predominantly rural area with an economy based chiefly on dairy farming, economic poisons were involved in 14 of the last 100 inquiries directed at our Poison Information Center in Hanover, New Hampshire. Not one of these cases, however, could be ascribed to an exposure that attended a farming operation.

If the dissemination of information about the hazardous nature of pesticides has served to reduce the incidence of occupational poisoning in the United States, the farmers in other countries appear not to be so fortunate. Parathion, which has been used so successfully as an insecticide by rice farmers, is estimated to have produced 6,000 cases of poisoning in the past 5 years in Japan.[8] In 1957 alone Japan experienced 570 accidental poisonings from this agent with 29 deaths, while an additional 519 persons chose this means to commit suicide.[5] Probably even higher rates can be anticipated in underdeveloped countries as economic poisons are used more extensively to stimulate their agricultural production. Among other groups, the Expert Committee on Insecticides of the World Health Organization is concerned about this eventuality.

Of course, people are not the only innocent victims of the economic poisons. Many unfortunate episodes can be found in the literature on veterinary medicine. A trivial but poignant example occurred recently in our own community. A local animal lover discovered fleas on the kittens of his favorite cat. He dutifully dusted the kittens with a homemade mixture containing 50 per cent DDT, and at last report the entire litter of four were healthy and flea-less. The mother cat, however, was not pleased with this powder on her brood. Apparently she spent the entire first night washing them in the accepted feline way. By the next morning the mother cat was suffering from tremors and incoordination; generalized convulsions began that afternoon and continued into the night, when she died in spite of a belated attempt to save her with several large doses of pentobarbital. The hazards of maternal love have been underestimated.

VOL. 9 195

One reassuring feature of the present situation is that the acute toxicity of almost every economic poison in current use is well defined. In some cases clinical reports have established the toxic syndrome in man and have demonstrated the effectiveness of recommended treatment programs. In other cases animal data provide a reasonably satisfactory basis for estimating the danger of accidental poisoning and the proper methods of handling it. Admittedly this information is not always in the possession of physicians who are called upon to treat these poison victims. Several up-to-date reference manuals in clinical toxicology[4] are now available to correct this defect, and the recent establishment of poison control centers in all parts of the country is proving to be a valuable way of compensating for the average physician's lack of specialized toxicologic information.

OL.
9
959

THEIR STATUS AS CUMULATIVE TOXIC HAZARDS

The ubiquity of economic poisons in modern society has provoked much discussion about the possible cumulative risk of poisoning arising from a series of singly inconsequential exposures repeated over a long period of time. Many claims and counter-claims have been proffered, but most of these convictions have been supported more by ardor than by data. The suspicion that pesticides pose very special long-term hazards to health was stimulated particularly by the discovery not only that DDT is a remarkably persistent compound out-of-doors but also that it resists in part the usual excretory and detoxication processes in vivo. As a result DDT tends to accumulate in the body fat of man and animals who are exposed to sufficient levels of it. That other pesticides are not recognized as sharing this property of DDT is not altogether reassuring to everyone.

Substantial numbers of organic gardeners, antifluoridationists, antivivisectionists, and others who are suspicious of science in general and "chemicals" in particular have made wild allegations not only that economic poisons are sapping the inherent biologic vigor of plants on which man depends for his food but also that they are reducing the vitality of man himself, so that he is more easily prey to cancer, heart disease, and the entire spectrum of degenerative diseases. That no reputable evidence has ever been presented in favor of such claims in no way inhibits dedicated obscurantists.

On the other hand many thoughtful and intelligent people have recognized the possibility of a cumulative threat to health in any widespread uncontrolled use of pesticides. The inevitable plea for legislative protection has produced at least one significant regulatory act. The Miller Pesticide Amendment to the Federal Food, Drug, and Cosmetic Act became Public Law No. 518 on July 22, 1954. This amendment charges the Secretary of the Department of Health, Education, and Welfare with the responsibility of establishing tolerances for pesticide chemicals in or on raw agricultural commodities, so that unsafe amounts do not find their way into our food. More than 1,500 individual tolerances are now listed in parts per million (p.p.m.), specifying the residue of each pesticide that is allowed on each of many food crops. In addition several economic poisons have been declared officially safe so that no formal tolerances are needed. A large number of others has been exempted from the requirement of F.D.A.

tolerances when applied to growing crops (but not when used after the harvest), while still others are exempt only when employed on raw agricultural commodities after they have been harvested. In a similar way tolerances for residues in meat and milk are specified. In practice the farmer conforms with these tolerances by using these chemicals only according to carefully prescribed treatment programs as tested by various experimental agricultural stations.

The same concern that brought forth the Miller Amendment has resulted in an important addition to the federal food law, which requires the safety of food additives to be established before their use in food for man or animals. This regulation, known as Public Law 85-929, 72 Stat. 1784, was signed by President Eisenhower on Sept. 6, 1958. As in the Miller Pesticide Amendment, the responsibility for furnishing proof that a given level of chemical is safe is placed upon the manufacturer or other group who petitions for the establishment of an F.D.A. tolerance or other regulatory directive. Among the data that the petitioner must submit in every case are the results of chronic toxicity studies in laboratory animals. Thus the law provides machinery for an impartial review of all available evidence concerning the toxicity of a substance so that permission for its use can be denied if the supporting data are considered inadequate.

Obviously the protection afforded by an officially established tolerance is no greater than the validity of the laboratory tests upon which it is predicated. Procedures that have become standardized and are used widely for the toxicologic evaluation of chemicals in food, drugs, and cosmetics are described by Lehman and associates.[6] In the usual program the test chemical is fed at several concentrations in the diet to groups of rats for a period of 2 years. A similar chronic feeding test for a period of one year is performed on a small group of dogs or some related species. From these studies a "no-effect" level in the diet is established for both kinds of test animals. In translating from a "no-effect" level in an animal diet to a "safe level" for man, a large safety factor is commonly adopted; its magnitude is varied in accordance with any relevant information, such as the chemical's metabolic fate in man. Obviously these studies are expensive and time consuming. Tolerances based upon them can certainly be accepted with a large measure of confidence, but neither this nor any other set of tests provides an absolute guarantee against a toxic injury in man, even against a toxic injury of the nonhypersensitivity type.

About one year ago in Denver, Colorado, a man who is said to have made extensive use of herbicides developed acute congestive heart failure shortly after spraying his lawn with 2,4-D. Six months ago a young woman in southern New Hampshire complained of severe weakness and irritability as late sequelae of an illness that occurred when a team of professional exterminators allegedly employed a Diazinon solution to spray the inside of a small shoe factory while the woman and her co-workers remained on the job. A few weeks ago in Rochester, New York, a middle-aged man with a well-established medical history of parathion poisoning a year ago developed severe and apparently persistent dyspnea. In each of these cases the attending physician questioned a possible relationship between the symptoms and the known exposure to an economic poison. Each of these inquiries found their way to my desk.

VOL 9 195

Although current knowledge about the pesticides does not support any one of these clinical suspicions, it is well to remind ourselves that the subacute and chronic toxicity of economic poisons may involve human reactions that are not yet defined or even suspected. As long as official tolerances and permissible dietary levels are based almost exclusively on studies in laboratory animals, there is no excuse for complacency about these values. Neither is there any excuse for alarm. The ultimate protection of the consumer lies in the alertness of physicians and scientists who report to the proper regulatory agency when and if an unexpected toxic reaction first makes its appearance among the few most susceptible members of society. Inquiries from physicians like those cited reflect a degree of alertness and a level of suspicion that are highly reassuring.

OL.
9
959

SUMMARY

Never before has a society produced so many biologically active chemicals and integrated them so fully into its economy and its culture. The services for which we are indebted to the economic poisons are many and undeniable. The control of arthropod-borne diseases is an example of one such achievement. The pesticides have also demonstrated their capacity to improve human nutrition by contributing significantly to a rise in agricultural productivity. On the debit side of the ledger is the capacity of many of these substances to produce severe intoxication in man. Accidental poisonings have and probably will continue to occur, but in this country the incidence of severe toxic insults is not alarming even among those engaged in such relatively hazardous occupations as farming. The threat of chronic injury from cumulative exposure has been materially reduced by legislation which prohibits pesticide residues on agricultural commodities in excess of conservatively prescribed limits. Any remaining risk of chronic poisoning is remote and justified by all the benefits that society derives from the use of these materials. The safety issue can never be settled by polemics or by fiat. In the ultimate analysis the good health of our farmers and the wholesomeness of our food supply can be guaranteed only by a scientific community that stays alert.

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EMOTIONAL DISORDERS, A PROBLEM IN OCCUPATIONAL MEDICINE

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EMOTIONAL disorders are ubiquitous and present to industry one of its most complicated medical problems. The industrial physician, like his colleague practicing in the community, recognizes that he devotes a major portion of his clinic time to a relatively small group of patients whose symptoms appear to be of emotional origin or are much modified by emotional factors. In the July, 1949, issue of *Industrial Medicine*, for example, W. J. Fulton reported in his job and time analysis of industrial medicine that 85 per cent of the medical services were utilized by 30 per cent of the workers whose problems were primarily emotional in character. Unlike his counterpart, however, the industrial physician has the additional responsibility of maintaining the health of the whole employee group who comprise the effective production team. In a very real sense the company is the patient. It is this added dimension of group health that makes occupational medicine alternately fascinating and frustrating.

Numerous articles appear with increasing frequency in professional and lay periodicals as evidence of concern with a variety of group problems in which emotional factors are important elements.[52-56] It is apparent from such articles that industry has a real and legitimate interest in emotional problems because of both human and economic implications. However, this has not always been the case, for industry's interest in mental hygiene is a relatively recent development.

During the past 50 years, particularly in the last three decades, there have simultaneously evolved several movements that prepared a proper atmosphere in industry for the development of measures aimed at preventing emotional disorders. These movements are: (1) development of occupational health as a preventive medical discipline, (2) development of the field of human relations, and (3) development of psychiatry in the community.

During this evolution each field has contributed to the body of knowledge of the others, elucidating aspects of human behavior. It can be seen that the practical application of psychiatric principles and techniques has not been possible until such development, and until there were in industry a recognition of the need for special help, the willingness to accept this help, and the availability of help that was appropriate.

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DEVELOPMENTS IN OCCUPATIONAL MEDICINE

Elsewhere in this issue (p. 85) Goldwater traces the historical development of occupational medicine to its present status and indicates the problems that will demand attention in the future. He shows that early in this century the industrial physician was primarily concerned with treating occupational injuries. In the subsequent decades, however, there was a gradual expansion in the focus of interest, so that today a medical program in industry is vastly more comprehensive and is preventive in orientation. This transition evolved in response to particular needs and as the scientists in the field developed concepts and techniques to meet these needs.

Probably the most significant factor that stimulated such development initially was the growing economic responsibility that health and welfare legislation placed upon industry. When, through workmen's compensation laws, for example, industry assumed greater financial liability for occupational injuries and illnesses, it became perfectly apparent that it was more sensible to prevent such losses than to shoulder the costs. In addition, the experiences in the two world wars demonstrated the importance of controlling environmental hazards and focused attention on the vital need of maintaining the health status of the employees if production schedules were to be met. These stimulated the needed research in clinical studies, field epidemiologic studies, and chemical and engineering techniques that culminated in the principles of environmental control and personnel protection which are the basis of modern occupational medicine. In the application of these principles there were developed such techniques as selective placement, evaluation and control of environmental hazards, periodic health appraisal, prepathogenetic tests for incipient disease, diagnosis of nonoccupational diseases, and health counselling and education.

Although there had been a few isolated early programs, it was not until such development that emotional disorders began to attract the attention of the industrial physician to a significant degree. Traditionally, industry had not considered this a problem of occupational origin nor of particular industrial significance. As the industrial physician applied epidemiologic techniques to his group, it soon became obvious that emotional factors were significant in a variety of considerations. In recent years there have been a multitude of reports that testify to this. For example, absenteeism, which has obvious economic implications for industry, has been shown to be related to emotional maladjustment and morale.[1-6] Alcoholism, which is also a problem in the larger community, is particularly costly because it occurs commonly among the experienced workers during their most productive years.[1,7-13] Several studies of accidents[1,7,14-19] have indicated the importance of emotional conflicts as predisposing factors in their occurrence. Similarly, problems relating to disability evaluation and rehabilitation,[1,2,20-22,39] the older employee,[1,23-25] and turnover[27,37-38] in industry require an appreciation of the emotional factors involved for their proper management. Then, too, as the workmen's compensation schedule was expanded and the interpretation of compensation laws liberalized, the functional aspects of impairment became more important. The economic and human losses

manifested in these problems are impossible to calculate. But they have stimulated the industrial physician and the management he counsels to inquire into what can be done to prevent or attenuate the problems. In general, the industrial physician has not as yet developed the tools to cope with them, although the need has become evident.

DEVELOPMENT OF HUMAN RELATIONS

Although industry has only recently become concerned with the clinical aspects of emotional disorders, it has for a longer time been very much interested in utilizing human resources effectively. Early efforts included the use of industrial engineers, such as F. W. Taylor and his successors, and industrial psychologists who developed intelligence and aptitude tests for selective placement. The prevailing view was essentially mechanistic until the work of Elton Mayo and his associates who started a series of studies to determine the effects of certain working conditions on productivity.[26,27] They demonstrated that industry is not exclusively an economic venture and showed the great importance of social interaction in industry, the formation of informal groups, and the influence of such groups on morale, motivation, and ultimately on production. Since these initial investigations a variety of scientists have turned their skills to an examination of the social and psychologic aspects of work. Such scientists include social psychologists, clinical psychologists, anthropologists, and sociologists.

At present there are in the country a number of study centers at graduate level, such as those at Michigan University, Harvard University, Yale, and Cornell, devoted to the teaching and the investigation of behavioral phenomena. The scope of their interests extends beyond the industrial setting, but many of the studies are concerned with behavior problems in industry. These range through selective placement, job appraisal, work evaluation, formal and informal organization structure, communications, group interaction, morale, motivation, personality, leadership, and industrial labor strife. Initially, the investigators pursued their studies from the point of view of their own disciplines, using their own theoretical systems, techniques, and languages. Experience, however, showed an overlapping of interests and demonstrated that many of these problems yielded best to interdisciplinary studies. The academic institutions provide an appropriate setting for the exchange of concepts and techniques that have been seen in more recent years. These common efforts comprise the new discipline known as human relations.

The literary output in this field is considerable and is found in several professional journals,[28-30] in a variety of books[26,27,31-34] and, of particular significance, in periodicals that reach industrial management. The reports of these studies have had a great impact upon management and have probably been most responsible for an appreciation of the "human factor" and for industry's "employee-centered" orientation. This is evidenced today by the considerable demand for specialists as consultants in these problems. In addition to the research centers, which also provide services to industry, there are many private consultation

agencies which offer management special assistance in response to these needs. As a group they have been highly successful in impressing upon management that special understanding and particular tools are needed to operate an organization that is both an economic and a social venture. In accounting for this success one must credit, among other things, a practical approach to recognizable, realistic problems in a way that can readily be communicated. Then, too, industry has had adequate experience in utilizing such consultants for special problems. The same has not been generally true, however, of psychiatry which has not been as successful in communicating with industry and which has several unique problems.

DEVELOPMENTS IN PSYCHIATRY

OL.
9
959

The practice of psychiatry has undergone remarkable changes in this century. Formerly, its locus was the custodial institution, a forbidding place of last refuge for many who needed to be isolated from the stressful demands of normal life and from whom the community demanded protection. The "asylum" was physically outside the community and rarely was it in the public consciousness. Any reference to it evoked feelings of anxiety, even futility. This was the atmosphere in which the psychiatrist worked, and inevitably he was identified with the stigma of the asylum. This was not a likely source of help for industry.

However, a variety of significant contributions have since profoundly changed the practice of psychiatry. Freud, his associates, and subsequent investigators developed a theoretical system for the formulation and treatment of emotional disorders. The introduction of somatic therapy and pharmacologic agents have provided valuable tools in shortening the hospitalization of patients and making them more amenable to psychotherapy. Not only are more patients being returned to community life, but it is also possible to treat as outpatients or ambulatory cases many who would formerly have been hospitalized. In addition, a multitude of people who are less severely disturbed have begun to seek help. The net result is a more hopeful attitude regarding the prognosis of mental illness and a greater confidence in the psychiatrist who has moved his practice into the community. Working beside his professional colleague in the general hospital, in various agencies, and privately, his role is more generally accepted and bears less of the old stigma. In the process the psychiatrist has developed a body of knowledge and techniques that is highly applicable to the management of the emotional disorders that confront the industrial physician.

The history of applying psychiatry's contributions in industry is brief and has been detailed elsewhere.[1,7,35,36] It is significant that psychiatrists were not utilized initially to handle clinical problems. They were recruited by imaginative managments to counsel with departments of personnel in selective placement, interviewing techniques, accident prevention, and problems of morale. Of special importance for industry has been the development of social psychiatry since 1940. This discipline may be loosely defined as the application of psychiatric and sociologic principles to the study of individual and group behavior. Actually, this definition is oversimplified and has been more fully elaborated by

Rennie.[40] World War II provided the initial stimulus to the growth of this field. Psychiatrists in industry and in the armed forces were responsible for maintaining the emotional health of plant and military personnel under abnormal conditions of stress. A great deal was learned from this unusual experience about the importance of leadership, motivation, morale, and communication to production and fighting efficiency. The remarkably high number of psychiatric casualties provided an opportunity to develop techniques of emotional first-aid and to gain further insights into the varieties and mechanisms of environmental stresses producing emotional disorders. From these and subsequent studies of groups have come a number of important works dealing with a society,[41] a community,[42,43] industries,[7,44-47] and a mental hospital,[48] to mention only a few of a rapidly expanding literature.

Most of these investigations share a common interest in identifying and evaluating the multiple factors in the interactions of humans and their environments that culminate in emotional disturbances. Their purpose ultimately is to provide a basis for so modifying the environment or attenuating human response as to prevent or reduce the occurrence of mental illness. The basic principles and techniques very closely parallel the epidemiologic approach of occupational medicine for the prevention of disease and can be readily adapted to the machinery already available to the industrial physician.

Despite the advances in the several fields described, there has not been a great demand in industry for psychiatrists. There are several probable explanations for this. First, an aura of anxiety surrounding the psychiatrist and mental illness persists in the community, although to a lesser degree than formerly. Bringing a psychiatrist into the plant is tantamount to an admission that it is a disturbed organization. Also, the presence of a psychiatrist evokes discomfort in some industrial physicians and management personnel. Following his visit to the United States, Mindus[35] reported in 1952 that there was still a failure in many quarters to appreciate the potential contributions psychiatry can make to industry. There are also important practical considerations. The field is not well enough known or regarded to attract psychiatrists to its practice. Nor are there many psychiatrists with the training that is required for an understanding of industry's milieu.[49] At present there are only a handful of properly qualified psychiatrists in industry to devote an appreciable portion of their time to both the clinical and preventive aspects of emotional disorders. The preventive aspects include such activities as counselling employees, training various members of management and the medical staff, counselling management in policy formulation, advising the personnel department in selective placement practices, employee evaluation, and finally in sorely needed research.[1,7,50,51]

Since psychiatrists in industry are rare, the bulk of emotional disorders are of necessity and quite appropriately the responsibility of the occupational health physician. Because of his role in the plant community he is a sensitive listening post for signs of disturbance. His record system and ready accessibility to all employees provide him with a unique apparatus to study the interactions of this environment and employees and to detect symptoms of incipient disorders. If he has the confidence of management he is also in a position to modify the

environment with proper counsel. His basic functions of selective placement, environmental control, periodic health appraisal, disability evaluation, health counselling and education, and first-aid treatment of nonoccupational disorders have been established.

Within this framework he must now adapt the knowledge and techniques of clinical and social psychiatry and human relations and apply them to his particular problems. He must of necessity do this, just as he must continually expand his armamentarium to solve other complicated environmental stresses such as radiations, noise, and air pollution. Only in this way can he hope to maintain the health of an effective work group.

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VOL
9
195

CHRONIC LEAD AND MERCURY POISONING: CONTEMPORARY VIEWS ON ANCIENT OCCUPATIONAL DISEASES

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OL.
9
959

LEAD and mercury are indeed ancient poisons; their toxic effects were known to Hippocrates and Pliny. The history of lead poisoning in this country has been traced back to colonial times.[1] The purpose of this paper is to outline how recently published results of clinical observations and research have improved and enlarged theoretical insight and practical experience.

Poisoning by both lead and mercury may occur in the form of acute poisoning. However, acute lead poisoning is hardly ever seen, and the term is generally misused to designate an acute exacerbation of chronic lead poisoning. In the past, acute mercury poisoning was not infrequent; it was caused by the use of mercurials for treatment and for suicidal purposes as well as by occupational exposure. Contemporary interest is focused on true chronic poisoning, i.e., that form of poisoning in which symptoms and signs do not follow one single exposure but are the result of continuous or repeated exposure.

CHRONIC LEAD POISONING IN ADULTS

The incidence of chronic lead poisoning in children is greater today than in adults, and the fatality and disabling effects are much more marked in children. Occupational poisoning in adults by inhalation of the dusts and fumes of inorganic lead is, however, still much more frequent than one would expect in view of the fact that exposure to lead has been greatly reduced in the industries that were known formerly as especially hazardous (painting, printing, manufacture of paints, storage batteries, metal alloys, printing type, glass and ceramics, etc.). The present Threshold Limit Value (Maximum Allowable Concentration)[2] of lead dust and fumes in air for an 8-hour daily exposure is 0.2 mg. per cubic meter. Although certain lead compounds, such as lead sulfide, are considered "insoluble" from a technical point of view, it must be pointed out that they may be dissolved in the human body and then become harmful.

Of more recent origin is the hazard of exposure to organic lead compounds. About 140 cases of lead encephalopathy acquired in the manufacture and handling of tetraethyl lead were reported by Kehoe, Thamann, and Cholak[3] in 1936. This hazard was soon practically eliminated. In World War II, a large number of

cases of chronic lead poisoning resulted from the cleaning of tanks in which tetraethyl lead had been stored. This operation, too, was quickly rendered harmless.

A history of hazardous exposure to lead suggests and supports, of course, a diagnosis of lead poisoning. *In order to arrive at the actual diagnosis, symptoms and signs of lead poisoning have to be in evidence.* While in the past severe symptoms and signs of a great variety were observed, most of the patients seen today show only anorexia, constipation, colic (with or without vomiting), and toxic neuritis. In spite of the fact that lead colic is the best known symptom of chronic lead poisoning, neither the site of the effect nor its nature is sufficiently understood.

Wristdrop and other forms of lead palsy are seen rarely today. The development of lead palsy does not depend upon the length of exposure to lead. Prior to 1925, when Aub and associates[4] published their findings, it had been assumed that the nerve was the site of action. Since then, it has been the prevailing opinion that the muscle is affected. However, the explanation given by Reznikoff and Aub[5] can no longer be considered valid. As Cantarow and Trumper[6] have pointed out, the low level of phosphocreatine and the marked interference with its resynthesis,[7] for which a direct action on intracellular enzyme systems may be responsible, readily can explain the muscular weakness, fatigability, and paralysis. Notwithstanding the general tendency to locate the injurious process in the muscle, the diagnosis of toxic peripheral neuritis is still preferred. There is, in many cases, sufficient evidence to justify this diagnosis. Various pathologic changes in the nerve tissue have been reported, but these are inconstant findings. Interference with enzymatic processes has been suggested also as the cause of the neuritis.[8] Hyslop and Kraus[9] concluded that the entire lower motor neuron is injured rather than the peripheral part only. The results of electromyographic studies appear to be in agreement with this statement. The chronaximetric studies by Lewy[10] have introduced a method to ascertain clinically inapparent early disorders of neuromuscular function and also late residual disorders. Electromyography appears to be a more practical approach, although the interpretation of results is still somewhat controversial[11]; regenerative processes have been demonstrated by the use of this method. Like lead palsy, lead encephalopathy is almost never seen at present in adults, and the classical clinical picture of convulsions, coma, delirium, toxic psychosis, aphasia, and visual changes has to be learned from the textbooks or from cases of lead poisoning in children.

Arthralgia, once a very frequent symptom, is still encountered occasionally; so-called "lead gout" never has been reported in this country. Of great importance and significance at present are reports that excess lead absorption leads to hypertension, nephrosclerosis, and general arteriosclerosis. The German literature, for instance, speaks of the "Bleiniere" (lead kidney). Vigdortchik[12] observed an increased incidence of hypertension and nephrosclerosis in Russian lead workers. More recently, European authors have stated that a high percentage of patients with the symptoms and signs of lead poisoning show impairment of renal function attributable to vascular injury. The results of American and some English investigations do not show a higher incidence of hypertension

or involvement of the kidneys. In discussing these negative findings, Henderson[13] points out that they should be considered against the background of the enormous reduction of exposure to lead in American industry. In a large series of cases of nephrosclerosis, this author has obtained a history of lead poisoning in childhood.

Some of the presently used laboratory tests are indicative only of excess absorption of lead. The so-called "lead line" is still widely mistaken as a sign of lead *poisoning*, while in reality its presence means merely *increased absorption* and deposition of lead; it is more likely to be absent than present. Methods for precise determination of the lead concentration in body fluids, especially in blood and urine, have only relatively recently become available as a means of determining lead absorption. Much new information on this subject has been published during the past two decades. The normal lead concentration in the whole blood among the American population has a range from 0.01 to 0.05 mg./100 ml., with a mean concentration of approximately 0.03 mg.; 95 per cent of the lead is in the erythrocytes. The corresponding figures for the lead concentration in the urine are 0.01 to 0.08 mg./1,000 ml., with a mean concentration slightly above 0.03 mg.[14,15] There is no constant correlation between the lead concentrations in blood and in urine. Urine examinations are preferred in the field, since changes in lead absorption are more clearly reflected in the urine levels. In the experience of the authors, blood examinations made during acute episodes of lead poisoning give, in general, valuable results. However, clinically evident lead poisoning may occur with very high or with only slightly increased lead levels; the latter is found especially after extended freedom from exposure. The mobilization of lead by one single infusion of edathamil calcium disodium has been used successfully to ascertain latent excess deposition of lead[16]; lead concentrations exceeding 1.0 mg./24 hours indicate increased lead deposits, although 0.5 mg./24 hours has been mentioned as a critical value.[17] According to old reports, lead was not to be found in the spinal fluid. However, lead is present in the spinal fluid even under normal conditions and may be much increased in lead poisoning, with or without nervous disease. Concentrations as high as 0.35 mg. to 0.493 mg./100 ml. have been reported.[18] The lead concentration in the spinal fluid is not correlated with the lead concentration in the blood.

Other tests indicate both excess absorption and deposition *and* initial injury. While, in spite of positive results of these tests, chronic lead poisoning in the absence of clinical evidence is called latent, coproporphyrinuria, stippling and polychromasia, and anemia are, of course, toxic effects of lead. Coproporphyrinuria is an early, constant, and marked effect of excess lead absorption. The concentrations of coproporphyrin III in the urine of normal human beings vary with constitution, diet, and activities but never exceed 0.08 mg./24 hours. Goldblatt and Goldblatt[19] present the opinion that the "medico-legal affirmation that a workman is *not* suffering from lead intoxication is rendered certain if coproporphyrinuria III is within normal limits." The determination of erythrocytic porphyrins has been claimed to be the best single test in lead poisoning.[20] A close correlation between mean values of lead and of coproporphyrin has been reported by Shiels and associates.[21] Of the urinary porphyrins, 88 to 99 per cent

VOL.
9
1959

are precursors of coproporphyrin; they are rapidly transformed and disintegrated by sunlight.[22] Kench, Lane, and Varley[23] have demonstrated that coproporphyrin I appears in the urine in appreciable amounts, but it is the increase in coproporphyrin III that is significant for poisoning by lead and other toxic materials. Like the lead line, the appearance of stippled erythrocytes in the peripheral blood has been widely misinterpreted and its significance overrated. According to Kehoe, Thamann, and Cholak,[24] 6 per cent of normal subjects show over 1,000 stippled cells per 1,000,000 erythrocytes, and larger numbers are to be found in disorders other than lead poisoning. The steady increase of stippled cells in persons exposed to lead certainly indicates increasing absorption. In acute episodes of chronic lead poisoning, counts of 10,000 and more stippled cells per 1,000,000 erythrocytes may be found. However, no increase of stippled cells, marked as it may be, permits by itself the diagnosis of lead poisoning; many cases with prominent and characteristic symptoms and signs occur without a large number of stippled cells. Stippled cells precede the anemia. The basophilic granules are not derived from the cell nucleus; they develop in the reticulum. They are formed in the bone marrow where they are more numerous than in the peripheral blood. The bone marrow shows a moderate degree of hyperactivity, and this may explain reticulocytosis. McCord, Minster, and Rehm[25] prefer a count of reticulocytes to that of stippled cells and have introduced the basophilic aggregation test. The developmental mechanism of the generally mild hypochromic anemia is still uncertain. The old theory that lead alters the cell membrane of the erythrocytes and thus leads to hemolysis has not been abandoned; it appears likely that this process takes place on precursor cells in the bone marrow.[26] Hemolysis is, in general, not evident in the peripheral blood, but cases of severe hemolytic anemia have been traced to lead. The part played by the interference with the synthesis of hemoglobin in the development of anemia needs further elucidation; in bone marrow cultures, lead has been found to inhibit the formation of hemoglobin.

Of the organic lead compounds, tetraethyl lead is practically the most important one, although other compounds toxic to animals may have industrial applicability. Tetraethyl lead is readily absorbed by inhalation; it can be absorbed also through the skin and in this way has caused isolated cases of severe poisoning. Tetraethyl lead is rather soluble in lipid tissues and thus accumulates especially in the central nervous system and the liver. The symptoms and signs of the cerebral disorder range from insomnia, anorexia, nausea and vomiting, and slight fall in blood pressure and body temperature to marked hypotension and hypothermia, tremors, delirium, and other severe manifestations.[27,28] Colic has not been observed, and stippling is absent or only slight; no lead line is present. It has been questioned recently whether poisoning by tetraethyl lead, as reported, is true chronic poisoning or, rather, subacute poisoning.[29,30]

CHRONIC MERCURY POISONING

Poisoning of hatters by mercury nitrate is remembered today almost as a fairy tale. Actually, it was less than 20 years ago that a field study by the United States Public Health Service[31] found more than 10 per cent of the examined felt

workers suffering from chronic mercury poisoning. The hazard in this industry as well as in many others, e.g., mining, manufacture of thermometers and barometers, testing departments, and laboratories, has been either eliminated or greatly reduced. During World War I, many cases of dermatitis originated from exposure to mercury fulminate, but this hazard, too, is obviously no longer important. The Threshold Limit Value for inorganic mercury is 0.1 mg. per cubic meter of air.[2]

In spite of the progress made, "epidemic" outbreaks of chronic mercury poisoning still occur. The most recent, described by Benning,[32] involved more than 60 workers employed in the manufacture of carbon brushes. These workers were exposed to air concentrations of 1.0 to 7.5 mg. mercury per cubic meter, The mercury concentrations in the blood ranged from 0.5 to 60.0 mcg./100 ml., and the urinary concentrations from 10.0 to 3,740 mcg./1,000 ml. These concentrations were not correlated with the symptoms observed. The normal level of mercury in the blood of unexposed persons has been given as 0.3 to 0.7 mcg./100 ml.[33]; unexposed persons excrete 0.1 to 1.0 mcg./24 hours.[34] A new sign of excess absorption of mercury has been published by Atkinson[35] and confirmed by others.[36,37] It consists of a brown discoloration of the anterior capsule of the lens and is called mercurialentis. The mercurial line on the gums is rarely seen.

In contrast to the acute form of mercury poisoning, chronic mercury poisoning affects mainly the central nervous system. The clinical picture reported in recent publications, e.g., by Benning[32] and by Oikawa,[38] corresponds largely to the classical description of the disorder. Prominent were gingivitis and stomatitis, with loosening of the teeth, metallic taste, irritability, intention tremors and shaking, fatigue and drowsiness, and gastrointestinal symptoms as well as many other phenomena; salivation was, in these cases, not a major complaint. Oikawa[38] found the serum cholinesterase activity decreased. Lesions of the statoacoustic apparatus with hearing loss[39] and progressive constriction of the visual field have been emphasized recently.[40] Increase of blood pressure has been seen in workers with mercury poisoning by Gobbato, Scansetti, and Capellaro.[41] These authors do not relate the increase in blood pressure to a kidney disorder, but occasional cases of reversible nephrosis have been observed by others.[42] Mild proteinuria may be encountered. The views on hematologic changes are controversial.

Organic mercury compounds have been in use as fungicides for over 40 years, but poisoning by these agents, especially by methyl mercury compounds, has been studied in detail only recently. These compounds are absorbed mostly by way of inhalation, but absorption takes place also through the skin and the mucous membranes of the mouth and the upper respiratory tract. The Threshold Limit Value of 0.01 mg. per cubic meter of air[2] has been established largely on the basis of Scandinavian investigations.[43,44] However, Dinman, Evans, and Linch[45] question the validity of this value. These authors point out the discordance between the urinary concentration of mercury and the symptoms and signs of poisoning by organic mercury; the latter were previously reported to occur at concentrations of 0.05 to 0.1 mg./1,000 ml. Stomatitis and salivation are not characteristic effects of organic mercury compounds. The signs and

symptoms are those of nervous disorders and consist of tremors, ataxia, dysarthria, and constriction of the visual fields. Memory and intelligence have been reported as both unaffected[46] and impaired.[47] Severe psychotic disorders have been seen.

TREATMENT

The basis of the contemporary treatment of both lead and mercury poisoning is the result of fundamental investigations concerning the nature of interaction of another metal, arsenic, with tissues. The elucidation of this problem by Peters, Stocken, and Thompson[48] led to the development of dimercaprol (British anti-lewisite, BAL) as an effective chelating agent for the inactivation of mercury as well as of arsenic and certain other heavy metals in the body. Unfortunately, this particular agent was burdened with numerous drawbacks as far as its use in the treatment of lead poisoning is concerned. With the introduction of the calcium chelate of ethylenediamine tetraacetic acid (edathamil calcium disodium, calcium disodium versenate) into therapy by Bessman, Ried, and Rubin[49] in 1952, the treatment of poisoning by lead came to be as efficacious as that of poisoning by mercury and related heavy metals. An early attempt by Kety and Letonoff[50] to apply the principle of chelation to the treatment of lead poisoning through the use of citrate was unsuccessful because citrate is metabolized in the body and thereby lead carried by the chelate is reliberated in the tissues. Versenate forms a stable, water-soluble, practically nontoxic chelate with lead, and this chelate is excreted unchanged in the urine. Thus, as with BAL in the case of mercury, so versenate in the case of lead prevents circulating metal from attacking sensitive tissues and removes the metal from tissues to which it has already become attached. Versenate does not seem to remove lead from the bone but only from tissue sites that come into intimate contact with the circulating blood. These drugs must be administered parenterally in order to be truly effective. At present other chelating agents such as penicillamine are under investigation as orally effective prophylactic and therapeutic agents in metal poisoning.

Although the use of BAL for the treatment of mercury poisoning and the use of versenate for the treatment of lead poisoning are highly successful in preventing the continuation of injury by the metal, it is evident that such damage as has already been done must continue to be treated by conservative methods. However, the rapid lightening of the toxic burden of sensitive tissues by these agents constitutes a major advance.

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VOL. 9 1959

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VOL.
9
1959

Announcement

The Sixth Meeting of the Association of the National European and Mediterranean Societies of Gastroenterology will be held in Leiden, the Netherlands, from April 20 to 24, 1960.

The main themes of the conference will be: (1) pathology of the small intestine and (2) hepatitis, cirrhosis hepatis, and their possible connection. Original reports on these subjects or any other gastroenterologic subject, either clinical or in the field of the basic sciences, are invited for submission and will be accepted for panel discussion or publication if approved by the Scientific Program Committee. Titles for papers together with a summary of not more than 200 words should be sent not later than Aug. 1, 1959, to Dr. B. K. Boom, Congress Office, Department of Gastroenterology, University Hospital, Leiden, the Netherlands.

For further information and registration, apply to the Congress Office of the Sixth Meeting of the Association of the National European and Mediterranean Societies of Gastroenterology, Department of Gastroenterology, University Hospital, Leiden, the Netherlands, or the Secretary of the national societies of gastroenterologists.